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CAPABILITIES IN WIDE ANGLE VISUAL TECHNOLOGY

Carl R. Driskell

Naval Training Equipment Center

Prepared for:

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December 1974

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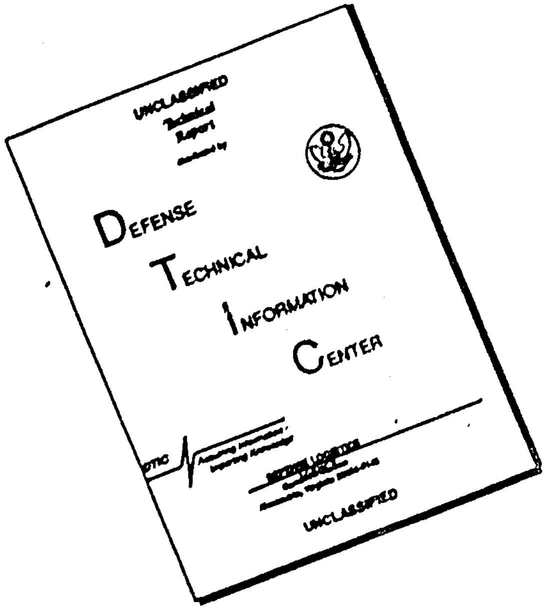

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This report provides a sound technological basis for the specification of advanced visual systems for state-of-the-art aircraft flight simulators. The results of a survey of current and near-term wide angle visual systems is presented. Hardware and training risks are assessed for the application of various image generation sources and wide angle visual systems to specific pilot training tasks. Specification language is provided as a guide for procurement of a wide angle visual system with a full mission capability.

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CAPABILITIES IN WIDE ANGLE VISUAL TECHNOLOGY

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December 1974

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PREFACE

The author expresses his gratitude to the people of the Naval Training Equipment Center, who contributed to this report; and especially to Mr. John McKechnie for his in-depth survey of wide angle visual systems and tabulation of data he collected.

To Messrs Joe Raffo and Gordon Palmer a sincere thank-you for their critical readings and significant suggestions particularly in the areas of specification language and risk assessment.

The report has been prepared with an Appendix which when detached can be used independently. Therefore, the Appendix pages have been numbered independent of the main report.

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SECTION I

INTRODUCTION

As part of the Aviation Wide Angle Visual Program, the Naval Training Equipment Center has conducted a survey and assessment of current and near-term capabilities in wide angle visual technology. The purpose of this report is to present the results of the survey for guidance relative to planned training device procurements beginning in FY 75.

SECTION II

STATEMENT OF THE PROBLEM

The current state-of-the-art does not offer a wide angle visual system with sufficient capabilities to meet all of the current pilot training requirements. Therefore, a sound technological basis is needed to specify cost-effective visual systems within budgetary constraints and within the current state-of-the-art. While a sound technological basis is needed to specify totally cost-effective visual systems with the highest return on life cycle investment, the Navy must also be able to state the sum total of its knowledge and experience to meet near term requirements.

SECTION III

PROCEDURE

DESCRIPTION OF SURVEY

An in depth literature survey of wide angle visual systems for flight simulation was conducted. All available data sources were used to review past, current and near future simulation technology. The data sources, method of access, extent and time frame of the survey are listed in Table 1. The survey was restricted to unprogrammed visual systems. Preprogrammed visual systems such as those which use motion picture film techniques were not included.

IDENTIFICATION OF FLIGHT TASKS

A review of current pilot training requirements was conducted. The review included personal interviews, minutes of recent planning meetings, and Navy directives. The major flight training tasks were identified for Conventional Takeoff and Landing (CTOL) and for Vertical Takeoff and Landing (VTOL) aircraft.

TABLE 1. SOURCES, METHODS OF ACCESS, EXTENT OF SURVEYS AND DATA TIME FRAME

Source	Method of Access	Extent of Survey	Data Time Frame
Flight Simulator Companies	Mailed Questionnaires	25 Systems	Presently in existance
DDC (Defense Documentation Center)	DDC Computer Search of DD Forms 1498	1800 NARDIS Reports*	1964 to 1974
Industry IR&D (Independent Research and Development) Reports	DDC Computer Search of DD Forms 1498	Approximately 50 reports	1964 to 1974
NASA Reports	NASA Scientific and Technical Information Facility	26 reports	1962 to 1974
Patents	Records of Patent Counsel at NTEC and Washington search office	70 patents	All to 1974

*Navy Automated Research and Development Information System

SECTION IV

RESULTS

INTRODUCTION

The capabilities and limitations of current wide angle visual systems are presented first for subsystem elements and secondly for overall systems. Every visual system possesses two fundamental subsystems, an image generation subsystem and a visual display subsystem. A general breakdown of these subsystems is provided with current capabilities and limitations of each element. Seven basic catagories of wide angle visual systems are identified. A system description is provided and performance parameters are listed for each system.

IMAGE GENERATION SUBSYSTEMS

The elements of each type of image generation subsystem are listed below with some of their current capabilities and limitations:

1. Camera/Model Systems

   a. Television Cameras (up to 1365 scan lines per frame, 30 frames per second, 800 television lines per picture height resolution, color)

   b. Video Chains (4 to 50 MHz video bandwidth)

   c. Terrain Model Boards (144:1 to 10,000:1 scales, up to 24 feet in height and 64 feet in length)

   d. Target Models (40:1 to 500:1 scales)

   e. Optical Probes

      (1) Fixed focal length for terrain model boards (up to 140 degrees field of view; Scheimphlug correction; roll, pitch and yaw servos)

      (2) Variable focal length for target models (up to 40:1 zoom capability)

   f. Gantries (velocities up to 12 inches per second, accelerations up to 8 inches per second per second, servo dynamic range up to 2000:1, Z travel 2 to 4 feet).

2. Computer-Generated Imagery (CGI) Systems

   a. General-Purpose Computer (Maintains active data base for edges within the display field of view, up to 6400 words)

b. Special Purpose Computer (Provides coordinate transformations, windowing, two-dimensional perspective, removes hidden surfaces, generates television formated signals, up to 3300 edges, color, up to 5 channels).

3. Film Transparency Systems (excluding motion picture film systems).

a. Transparencies

(1) Spherical (sky with mountainous horizon and clouds for attitude and heading cues, ground with pattern for altitude and heading cues, no translation cues)

(2) Planar (terrain and cultural scenes, translational cues, 4 foot diameter discs up to 6 foot square transparencies, 50:1 up to 5000:1 scales)

b. Point Light Sources (arc lamps, incandescent lamps).

VISUAL DISPLAY SUBSYSTEMS

The elements of each generic type of visual display subsystem are listed below:

1. Real Image Systems

a. Screens

(1) Flat (front or rear projected, wide angle coverage with side-by-side arrangement, gain depends on field of view and number and separation of viewers)

(2) Spherical (up to 360° coverage, gain depends on number and separation of viewers and on separation of projectors from viewers)

b. Television Projectors

(1) Monochrome Cathode Ray Tube (CRT) Projectors (up to 1225 scan lines per frame, 30 frames per second, 700 television lines per picture height resolution, up to 500 lumens light flux output)

(2) Color CRT projectors (up to 1229 scan lines per frame, 30 frames per second, up to 1000 television lines per picture height resolution, up to 2200 lumens light flux output with 6 CRT's)

(3) Monochrome light valves (up to 1203 scan lines per frame, 30 frames per second, up to 1000 television lines per picture height horizontal and 700 television lines per picture height vertical resolution at 945 line scan, 4000 lumens light flux output)

(4) Color Light Valves

(a) Simultaneous color (up to 525 lines per frame, 30 frames per second, 600 television lines per picture height horizontal and 350 television lines per picture height vertical resolution, 3600 lumens of light flux output)

(b) Field sequential (up to 735 scan lines per frame, 150 fields per second, 600 television lines per picture height resolution, 900 lumens of light flux output)

c. Optics

(1) Refractive

(2) Reflective.

2. Virtual Image Systems

a. Mirror/Beamsplitter Optics (illuminated by monochrome or color CRT, typically to 36 degrees vertical by 48 degrees horizontal field of views, 18 percent light transmission efficiency, can be arranged in row/column matrix for wide angle coverage)

b. Pancake Window Optics (illuminated by high-brightness CRT or television projector, up to 80 degree field of view, 1 percent light transmission efficiency, can be arranged in a dodecahedron mosaic pattern for wide angle coverage).

WIDE ANGLE VISUAL SYSTEMS

The results of the wide angle visual system survey are illustrated in Table 2. Most of the aviation wide angle visual systems that are operational now, or that will be operational within the next year, fall into seven basic catagories. These catagories, or system types, are identified in Table 2 as systems A through G. Performance parameters are listed for what is considered to be the best of each system type. The generic type of each visual display subsystem is identified by letter code(s). These identity codes are defined in Table 3. A brief description of each of the seven basic wide angle visual systems is provided below:

A

TABLE 2. WIDE ANGLE VISUAL SYSTEM PERFORMANCE PARAMETERS

Performance Parameters \ Wide Angle Visual Systems	A	B	C	D
Background Display				
Type (See Table 3)	H	PS	CM	CP
Number of Channels	2	1	6	7
Resolution, Center (Arc Min/OLP)	Unknown	10-15	11	14
Resolution, Edge (Arc Min/OLP)	Unknown	10-15	11	14
Field -of-View, Total (Deg)	360H X 150V	266HX137V	108H X 48V	240H X
Field-of-View, Per Channel (Deg)	60 CRT Insert	Not Applicable	36H X 24V	75
Luminance (Ft-L)	.1	.5 to 1.0	8	6
Contrast		15:1	20:1	10:1
Color	PS-Yes, CM-Yes	Yes	Yes	No
Refresh Rate (No./Sec)	Continuous &60	Continuous	60	30
Lag (Sec			0.05	.1
Position Accuracy (Deg)		0.3	1	Less t
Geometric Distortion (Percent)		Less than 1	Less than 2	Less t
Target Display				
Type (See Table 3)	CG/SR/CM	CG/SR	None	None
Resolution, Max FOV (Arc Min/OLP)	1.7	6	-	-
Field-of-View, Max (Deg)	10	15 and 60	-	-
Luminance (Ft-L)	.4	1.5 to 3	-	-
Contrast		15:1	-	-
Color	Yes, CG, CM	No	-	-
Refresh Rate (No./Sec)	30	30	-	-
Lag (Sec)		0.1	-	-
Position Accuracy (Deg)			-	-
Geometric Distortion (Percent)	Less than 1	Less than 5	-	-
Aircraft Flight Performance Envelope				
Altitude Range, Min/Max (Ft)	0/100,000	50/10,000	10/32,768	0/35,00
Maneuvering Area (NM X NM)			4 X 11	50^2 or
Velocity (Knots)	1400	600	550	Unlimit
Acceleration (G's)	10	6	4	Unlimit
Pitch Excursions (Deg)	Unlimited	± 90	Unlimited	Unlimit
Pitch Velocity (Deg/Sec^2)	300	± 120	60	Unlimit
Pitch Acceleration (Deg/Sec^2)		± 180	80	Unlimit
Roll Excursion (Deg)	Unlimited	Unlimited	Unlimited	Unlimit
Roll Velocity (Deg/Sec)	300	± 240	360	Unlimit
Roll Acceleration (Deg/Sec^2)		± 960	150	Unlimit
Heading Excursion (Deg)	Unlimited	Unlimited	Unlimited	Unlimit
Heading Velocity (Deg/Sec)	300	± 120	60	Unlimit
Heading Acceleration (Deg/Sec^2)	300	± 180	80	Unlimit
Computer Rates				
Motion Equations (Cycles/Sec)	20 to 100	20 and 40	20	7.5
Command Signals (Cycles/Sec)		Approx. 30	20	15
Display Size, Width X Length X Ht (Ft)	20X20X20	16X16X16	11 x 8 x 8	16 x 16
Display Weight (Lbs)	6000	Approx. 1000	3000	13,000

B

METERS

	C	D	E	F	G
	CM	CP	CP	TR	PP
	6	7	8	3	1
	11	14	17	20	4 to 15
	11	14	17	20	4 to 15
	108H X 48V	240H X 160V	300H X 142V	180H X 60V	200H X 60V
ble	36H X 24V	75	72	60H X 60V	200H X 60V
	8	6	2	3	1 to 5
	20:1	10:1	10:1	20:1	15:1
	Yes	No	No	Yes	Yes
	60	30	60	30	Continuous
	0.05	.1	.1	0.1	
	1	Less than 1	1	Varies w/Angle	Varies w/Alt
	Less than 2	Less than 1	Less than 2	Varies w/Angle	Varies w/Alt
	None	None	CP/SR	None	None
	-	-	4.5	-	-
	-	-	40	-	-
	-	-	8	-	-
	-	-	20:1	-	-
	-	-	No	-	-
	-	-	60	-	-
	-	-	0.1	-	-
	-	-	Less than 1	-	-
5	-	-	Less than 2	-	-
	10/32,768	0/35,[illegible]	0/65,000	0 to 500,000	5 to 25,000
	4 X 11	50^2 or 1250^2	50 X 50	200 X 200	4 X 4(X Scale)
	550	Unlimited	800	Unlimited	K X Scale
	4	Unlimited	-5 to +10	Unlimited	K X Scale
	Unlimited	Unlimited	Unlimited	Unlimited	±20
	60	Unlimited	60	Unlimited	±40
	80	Unlimited	100	Unlimited	±229
	Unlimited	Unlimited	Unlimited	Unlimited	±20
	360	Unlimited	300	Unlimited	±40
	150	Unlimited	150	Unlimited	±224
	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
	60	Unlimited	60	Unlimited	±57.3
	80	Unlimited	100	Unlimited	±86
	20	7.5	20	20	100/50/25
	20	15	20	20	25
	11 x 8 x 8	16 x 16 x 13	14 x 17 x 13	21X16X7	25X25X20
00	3000	13,000	9500	5000	Unknown

TABLE 3. IDENTITY CODES OF VISUAL SYSTEM GENERIC TYPES

System Type Identity Code	System Description
CG	CRT (Cathode Ray Tube) projector gimbal mounted or with gimballed optics and spherical display screen
CP	CRT with pancake window, virtual image optics
CM	CRT with mirror/beam splitter, virtual image optics
H	Hybrid-point light source with spherical transparency and spherical display screen plus a CRT with virtual image optics
TF	Television projector(s), front projected, with spherical display screen
TR	Television projector(s), rear projected, with flat display screen
PP	Point light source planar transparency and spherical screen
PS	Point light source(s) with spherical transparency(ies)
SR	Shrunken television raster capability with CRT

System A is comprised of a spherical screen on which two aircraft target images are projected. A window with mirror/ beamsplitter virtual image optics is mounted in front of the cockpit. This window utilizes a CRT and two target projectors to provide a virtual image display of the background scene and the target images within the forward 60 degree field of view. A total of six target projectors are used, two on each side of the cockpit and two for the forward virtual image window. The target images are derived from two television cameras which view gimbal mounted three-dimensional aircraft models. Each target image is switched from one projector to another as the target image traverses from one side of the screen to the other or into or out of the forward 60 degree virtual image window. The background scene is projected onto the screen by a sky-earth projector comprised of two internally lighted transparent hemispheres. The sky-earth projector is gimbal mounted behind the cockpit near the center of the spherical screen. The sky contains scattered clouds and the ground has a terrain pattern. The hemispheres are rotated to create the illusion of aircraft attitude and heading changes. The point light source is moved within the terrain hemisphere to create the illusion of ground growth with altitude changes. No translational cues are provided in the background scene. The background scene for the forward virtual image window is derived from a television camera which views a background scene on a gimbal mounted sphere. Currently, a system of this type is being used as a research tool in the design of new aircraft and aircraft systems. The forward 60 degree virtual image window is used in the design and development of operational headsup display systems. This visual system provides visual simulation for two-on-one air-to-air combat. However, the system is limited in application since it lacks a capability for taxiing, takeoff and landing, and translation over terrain.

System B is comprised of a spherical screen on which a background scene and a target image are projected. A sky-earth projector, comprised of two internally lighted transparent hemispheres, is gimbal mounted above and behind the cockpit to project a sky and terrain scene. The sky and terrain are without distinctive features except for clouds and a jagged horizon representing distant mountain peaks. The hemispheres are rotated to create the illusion of aircraft attitude and heading changes. A narrow angle CRT projector is gimbal mounted between the background projector and the cockpit to superimpose an aircraft image on the background scene. The target image is generated by a television camera which views a three-dimensional aircraft model. The model is encapsulated in a transparent ball which is servo driven to present the aircraft model in proper perspective to the camera. This system can provide a high resolution target image and a continuous display with no image breakup due to window interfaces, but it is limited in application.

It does not provide adequate visual simulation for taxiing, takeoff and landing, or translation over the terrain. Heavy reliance must be placed on cockpit instruments particularly when the horizon is not in view because the terrain scene lacks any distinctive features. Currently, a system of this type is being used as an engineering development tool in the design of new aircraft.

System C is comprised of a matrix of high resolution color television monitors and mirror/beamsplitter virtual image optics. The wide angle image is derived from a high resolution color television camera and a three-dimensional model board. The camera is gantry mounted and is equipped with a wide angle optical probe. This system provides visual simulation for taxiing, takeoff and landing and circling approaches and air-to-ground weapons delivery; but it is a part-task simulator which does not provide the high resolution target imagery for air-to-air combat simulation. Currently, a system of this type is being fabricated as an experimental visual system for research in pilot training.

System D is comprised of multiple pentagon shaped display channels which are mosaiced together to form a partial dodecahedron shell surrounding the cockpit. Each display channel has a CRT with pancake window virtual image optics. Since the pancake window optics are only one percent efficient, large, high brightness, monochrome CRT's are used. Color CRT's with the required brightness are beyond the state-of-the-art. A visual environment for taxiing, field takeoff and landing, aerobatics and formation flying is provided by a CGI (Computer Generated Imagery) system. Currently, a two-cockpit system of this type is being installed for use as an experimental visual system for research in undergraduate pilot training. This system is limited in application since high resolution target imagery is not provided for air-to-air combat simulation.

System E is comprised of multiple pentagon shaped display channels which are mosaiced together to form a partial dodecahedron shell surrounding the cockpit in a manner similar to System D. Each display channel has a CRT with pancake window virtual image optics. Unlike System D, each CRT has a shruken raster capability to provide high resolution target imagery. The target imagery is generated by a television camera which views a gimbal mounted aircraft model. The background scene of terrain and sky is computer-generated. The background and aircraft images will be displayed in time sequence. The background scene will be displayed on full size rasters while the target image will be superimposed on the background with a shrunken raster. The shrunken raster will provide high resolution in the target image where it is needed. However, the display electronics of each window will require very high performance subsystems. These include wide bandwidth video amplifiers and linear horizontal and vertical deflection systems. The deflection systems must be linear and accurately matched to maintain image continuity as the aircraft image moves across window interfaces and to maintain proper image perspective as the aircraft raster is changed in size to simulate a change in target range. The one percent efficiency of the pancake windows necessitates the use of high brightness, monochrome CRT's. Currently, a two cockpit system of this type is being installed for use as an experimental visual system for research in air combat tactics and in air-to-air combat training. This system is limited in application since simulation of take-off and landing is not provided.

System F is comprised of a single row of flat rear projection screens mounted side-by-side around the cockpit. Each screen is illuminated by a color light valve television projector. A CGI system feeds colored surface imagery to each of the television projectors. A visual environment is provided for taxiing, takeoff and landing, formation flying and weapons delivery. Currently, an experimental system of this type is being evaluated to determine its potential for undergraduate pilot training. This system is limited in application since it lacks sufficient resolution for air-to-air combat simulation.

System G is comprised of a spherical screen and a point light source with a gimbal mounted planar transparency. The gimbal system translates and rotates the transparency with respect to the point light source to portray motion of the simulated vehicle. The scale of the scene can be changed in steps by changing the transparency. Some downtime is required to change transparencies. The point light source provides a continuous wide angle display with a translational background which is desirable for simulation of taxiing, takeoff and landing. However, the point light source has the disadvantages of relatively poor resolution at close ranges and low brightness, and a very limited geographical area. The geographical area is particularly limited where low scale factors are used to provide the needed resolution for takeoff and landing and low altitude flight.

SECTION V
DISCUSSION

HISTORICAL DEVELOPMENT OF VISUAL SIMULATOR TECHNIQUES

The historical development of visual simulator techniques will be addressed briefly to set the stage for discussion of current goals potentials, requirements and capabilities of wide angle visual technology. Aviation visual systems date back as early as 1939 when a simple cloud simulator was attached to a Link AN-T-18 basic flight trainer. The cloud simulator was comprised of a point light source which projected cloud images from a film transparency onto a screen. Since this simple beginning, point light source techniques have been refined, optical image generation systems have been devised, semiprogrammed motion picture systems have been produced, and complex television systems with camera/ model, film, and computer image generation systems have been developed. Current efforts are directed toward the refinement of existing techniques and the development of new techniques particularly in television and holography. For example, new television techniques are being developed to electronically inset high resolution target imagery into wide angle background scenes, and new holographic techniques are being developed to provide flexible three-dimensional imagery for television display systems.

Current visual simulation technology provides the capability to simulate a visual environment for essentially all of the major flight tasks on a part task basis. For example, National Aeronautics and Space Administration (NASA) currently has in operation a two-cockpit Differential Maneuvering Simulator which provides the visual environment for two pilots to engage in realistic air-to-air combat. This system lacks the capability of takeoff and landing. The Air Force is funding the development of a two-cockpit Advanced Simulator in Undergraduate Pilot Training (ASUPT) which provides the visual environment for taxi, field takeoff and landing, aerobatics and formation flying. This system lacks the high resolution target imagery required for air-to-air combat. A single full mission simulator with high resolution target imagery for air-to-air combat and with sufficient background detail for takeoff and landing remains a research and development goal.

NEAR TERM GOALS

Near term goals for the next two to three years are to assimilate the sum total of existing visual system knowledge and to use this knowledge in the engineering development of wide angle visual systems to meet immediate part task training requirements. The Navy's Aviation Wide Angle Visual Program will provide this knowledge through a continuing survey of Government and industry research and development efforts and through the in-house advanced development of flexible cockpit-motion, visual systems. One system will be developed for Conventional Takeoff and Landing (CTOL) aircraft simulation and a second system will be developed for Vertical Takeoff and Landing (VTOL) aircraft simulation. Each system will use independent television projectors and a wide angle screen. Wide angle projection techniques will be used to display the background scene over a wide area while narrow angle target projectors will provide high resolution target imagery over a smaller area. The projectors will be fed from a flexible image storage system which will include three-dimensional models, two-dimensional film, and computer-generated imagery. The objectives of the Aviation Wide Angle Visual Program are: (1) to develop and demonstrate the capability and training effectiveness of wide angle visual systems with high resolution target imagery; (2) to provide a flexible image storage system including 3-dimensional models and computer-generated imagery; and (3) to develop flexible cockpit-motion-visual systems for CTOL and VTOL simulation. The CTOL and VTOL installation will provide the basis for the development of future advanced flight simulators with wide angle visual systems. The hardware, developed by this program, will provide a flexible, modifiable development and analysis tool with which future advanced flight simulator and visual system designs can be tested and evaluated. The results of these tests will establish design criteria, and will demonstrate feasibility and capability of new visual-motion systems suitable for contract procurement. Figure 1 illustrates the information flow within the Naval Training Equipment Center. This flow of information is essential to accomplish the research and engineering goals.

MIDTERM GOALS

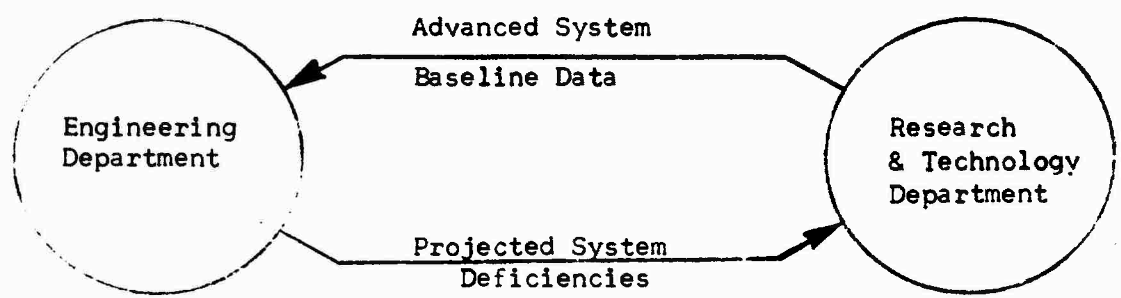
Efforts over the next three to five years will be directed toward general upgrading of near term capabilities and determining the most effective mix of visual system techniques. For example, the Aviation Wide Angle Visual Program will develop advanced real image display techniques with dynamic background imagery and will explore the best mix of camera/model, film, and computer-generated imagery.

LONG TERM POTENTIALS

The potential for the next five to ten years is to provide full field of view simulation with high resolution imagery over a wide area. It is anticipated that computer-generated imagery has the potential to accomplish this objective for most, if not all, pilot training tasks. With further advances in display technology, the visual capabilities for a full mission flight simulator may be developed within the next five to ten years.

FLIGHT TRAINING TASK REQUIREMENTS

Since each flight training task has a unique set of visual simulation requirements, the requirements will be listed individually for



Responsibilities:

System synthesis
Deficiency definitions
Specification generation

Responsibilities:

System analysis
Feasibility determination
Capability determination
Human Factors requirements

Figure 1. Information Flow within NAVTRAEQUIPCEN

each major CTOL and VTOL training task. However, the cited visual system requirements are based on engineering judgement rather than on any in depth analysis. A detailed analysis of specific flight training requirements should be made prior to the procurement of any aircraft specific wide angle visual system. Human factors data from the Aviation Wide Angle Visual Program will contribute to future analyses.

CTOL TRAINING TASKS

1. Circling Carrier Takeoff and Landing (day and night)

   a. Wide angle seascape

   b. Carrier image with wake (maneuverable within wide seascape)

   c. Colored point lights

      (1) FLOLS (Fresnel Lens Optical Landing System)
      (2) Deck lighting (night)

   d. Special Effects

      (1) Fog and haze
      (2) Overcast and undercast
      (3) Visual breakout
      (4) Seastate (carrier roll, pitch and heave)

2. Field Takeoff and Landing (day and night)

   a. Narrow viewing angle (wide viewing angle preferred for circling approach)

   b. Airfield visual environment

   c. Colored point lights

      (1) Field FLOLS
      (2) Cultural and runway lights

   d. Special Effects

      (1) Fog and haze
      (2) Overcast and undercast
      (3) Visual breakout

3. Air-to-Air Combat (day)

   a. Wide angle sky/earth scene (with ground growth for altitude cue)

   b. High resolution aircraft image(s) (maneuverable throughout the sky/earth scene)

   c. Special effects

      (1) Grayout (due to high G forces)
      (2) Undercast

4. Air-to-Ground Weaponry (day)

   a. Wide angle sky/terrain scene (with ground growth for altitude cue)

   b. High resolution ground target (target circle, tank, etc.)

   c. Special Effects

      (1) Grayout (due to high G forces)

5. Formation Flight (day)

   a. Wide angle sky/earth scene

   b. Formation flight aircraft image (maneuverable throughout the sky/earth scene)

   c. Special Effects

      (1) Fog and haze
      (2) Undercast

6. In-Flight Refueling (day)

   a. Wide angle sky/earth scene

   b. Tanker aircraft image

   c. Special Effects

      (1) Fog and haze
      (2) Undercast

7. Aerobatics (day)

   a. Wide angle sky/earth scene (with ground growth and translation)

A comprehensive list of basic jet aircraft maneuvers is provided in Table 4. The adequate and desired field of view requirements are indicated for each maneuver. These data were taken from reference 1.

VTOL TRAINING TASKS

1. Ship Takeoff and Landing (day and night)

   a. Wide angle seascape

   b. Ship image (maneuverable within wide seascape)

TABLE 4. ESTIMATED FIELD OF VIEW REQUIREMENTS FOR BASIC JET AIRCRAFT MANEUVERS

Maneuver	Adequate		Desired	
	H	V	H	V
Carrier Rendezvous (Wingman)	150		180	
Carrier Approach and Landing	180	45	240	
Takeoff	120		180	90
Landing Pattern Entry (Break)	180	45	240	60
Landing Pattern	180	45	240	60
Turn Pattern	120		180	
Clearing Turns	120	60	180	90
Break-Turn Stall	120		180	
Power Off Stall	120		180	
Landing Attitude Maneuver	120		180	
Landing Attitude Stall	120		180	
Approach Turn Stall	120		180	
Steep Turn Stall	120		180	
Boost Off Exercise	120		180	
Spin	120	105	180	145
Minimum Radius Turn	120		180	
Aileron Roll		25		25
Barrel Roll	180	90	240	120
Wingover	180	90	240	120
Loop	120	135	180	180
Immelmann	120	135	180	180
One-half Cuban Eight	120	135	180	180
Low Visibility Approach	180	60	240	90
Section Takeoff (Wingman)	150		180	
Section Parade (Wingman)	150		180	30
Parade Turns Out (Wingman)	150		180	
Parade Turns In (Wingman)	150		180	30
Basic Crossunder (Wingman)	150	75	180	90
Break-Up and Rendezvous (Wingman)	150		180	
Underrunning (Wingman)	180		240	30
Lead Change (Old Leader)	240	75	240	120
Section Cruise (Wingman)	120	45	180	45
Standard Crossunder (Wingman)	150	75	180	90
Cruise Turns Out (Wingman)	120	60	180	90
Cruise Turns In (Wingman)	120	60	180	90
Division Balanced Parade (Wingmen)	150		180	30
Division Echelon Parade (Wingmen)	150		180	30
Division Joinup (Wingmen)	150		180	30
Division Lead Change (Old Leader)	240	75	240	90
Gunnery Pattern	300	35	320	30

c. Point lights (night)

d. LSE (Landing Signal Enlistedman)

e. Special Effects

(1) Fog and haze
(2) Overcast and undercast
(3) Visual breakout
(4) Sea state (ship pitch, roll and heave)

2. Field Takeoff and Landing (day and night)

a. Narrow angle (large depression angle for chin windows)

b. Airfield visual environment

c. Special Effects

(1) Fog and haze
(2) Overcast and undercast
(3) Visual breakout

3. Confined Area Maneuvering (day and night)

a. Narrow viewing angle (large depression angle for chin windows)

b. Confined landing area visual environment

c. Special Effects

(1) Fog and haze
(2) Beacon light (night)

4. In-Flight Refueling from Tanker Aircraft (day)

a. Wide angle sky/earth scene

b. Tanker aircraft image (maneuverable within sky/earth scene)

c. Special Effects

(1) Fog and haze
(2) Undercast

5. In-Flight Refueling from Ship Fantail (day)

a. Wide angle seascape

b. Ship (oiler) image (maneuverable within seascape)

c. Special Effects

(1) Fog and haze
(2) Undercast

6. Search and Rescue (day)

a. Wide angle seascape and/or terrain scene

b. Survivor image

7. Air-to-Ground Weaponry (day)

a. Wide angle sky/terrain scene (with ground growth for altitude cue)

b. High resolution ground targets

8. Autorotation (day)

a. Wide angle sky/terrain scene (with ground growth for altitude cue)

b. Landing area visual environment

TRAINING PRIORITIES

Training priorities will be established with the continual guidance from NAVAIR and CNO. Training cost effectiveness will depend upon substitution ratios as dictated by DoD, the number and capability of simulators available, and the utilization ratio of the fleet.

PRESENT VISUAL SYSTEM LIMITATIONS

A summary of present and near-term visual system characteristics is provided in Table 5. The range of performance values is shown for each system parameter. The system or systems that exhibit each end of the parametric limit are identified by letter codes. Performance parameters for each system type are listed in Table 2, and a description of each system type is provided in Section IV.

It would be desirable to build a system with all of the favorable parametric values of Table 5, the more favorable value being sometimes at the lower limit and some the upper limit depending on the parameter. Unfortunately, this is not possible because many of the parameters involve tradeoffs with other related parameters. Table 6 indicates some of the parameters that interact in visual systems. In general, improvement of one parameter will result in the degradation of a related parameter.

TABLE 5. RANGE OF WIDE ANGLE VISUAL SYSTEM PERFORMANCE PARAMETERS

Performance Parameters	Lower Limit Data	Lower Limit System Type*	Upper Limit Data	Upper Limit System Type*
Background Display				
Number of Channels	1	B	8	E
Resolution, Center (Arc Min/OLP)	4	G	20	F
Resolution, Edge (Arc Min/OLP)	4	G	20	F
Field-of-View, Total (Deg)	108 x 48	C	300 x 142	E
Field-of-View, Per Channel (Deg)	36X24	C	360	A
Luminance (Ft-L)	.1	A	8	C
Contrast	10:1	D,E	20:1	C,F
Color	Monochrome	D,E	Full Color	C,F,G
Refresh Rate (No./Sec)	30	D,F	Continuous	B
Lag (Sec)	.05	C	.1	D,E,F,
Position Accuracy (Deg)	.3	B	Varies w/Alt	G
Geometric Distortion (Percent)	Less than 1	B,D,E	Varies w/Alt	G
Target Display				
Resolution, Max FOV (Arc Min/OLP)	1.7	A	6	B
Field-of-View, Max (Deg)	10	A	60	B
Luminance (Ft-L)	0.4	A	8	E
Contrast	15:1	B	20:1	E
Color	Monochrome	B.E	Full Color	A
Refresh Rate (No./Sec)	30	A,B	60	E
Lag (Sec)	0.1	B,E	0.1	B,E
Position Accuracy (Deg)	1	E	Less than 1	E
Geometric Distortion (Percent)	Less than 1	A	Less than 5	B
Aircraft Flight Performance Envelope				
Altitude Range, Min/Max (Ft)	50/10,000	B	0/500,000	F
Maneuvering Area (NM X NM)	4x4 (X Scale)	G	1250 X 1250	D
Velocity (Knots)	550	C	1400	A
Acceleration (G's)	0.09	G	Unlimited	D,F
Pitch Excursions (Deg)	±20	G	Unlimited	ACDEF
Pitch Velocity (Deg/Sec^2)	±40	G	Unlimited	D,F
Pitch Acceleration (Deg/Sec^2)	80	C	Unlimited	D,F
Roll Excursion (Deg)	±20	G	Unlimited	ABCDEF
Roll Velocity (Deg/Sec)	±40	G	Unlimited	D,F
Roll Acceleration (Deg/Sec^2)	150	C	Unlimited	D,F
Heading Excursion (Deg)	Unlimited	All	Unlimited	All
Heading Velocity (Deg/Sec)	57.3	G	Unlimited	D,F
Heading Acceleration (Deg/Sec^2)	80	C	Unlimited	D,F
Computer Rates				
Motion Equations (Cycles/Sec)	7.5	D	100	A,G
Command Signals (Cycles/Sec)	15	D	30	B
Display Size, Width X Length X Ht (Ft)	11 x 8 x 8	C	25 x 25 x20	G
Display Weight (Lbs)	1000	B	13,000	D

* See Table 2.

TABLE 6. VISUAL SYSTEM PARAMETER INTERACTION

PERFORMANCE PARAMETERS	Number of Channels	Field-of-View per Channel	Luminance	Contrast	Color	Refresh Rate	Image Generation Source	Type of Display
Number of Channels		X						X
Field-of-View per Channel	X							X
Resolution		X	X	X	X		X	
Luminance		X		X	X	X		X
Contrast			X		X	X		
Color			X	X			X	
Refresh Rate			X	X			X	
Lag			X			X	X	X
Position Accuracy						X	X	X
Geometric Distortion		X					X	X
Maneuvering Area							X	
Display Size	X	X						X
Display Weight	X							X

For example, a wide field of view is usually accomplished at the expense of image resolution and brightness. Figures 2 and 3 illustrate some of the constraints encountered in the tradeoff of resolution and brightness for a greater field of view. The family of curves in Figure 2 indicates that the limiting resolution of a television display system is degraded as the display field of view is increased. The family of curves in Figure 3 indicate that the brightness of a projected image on a spherical display screen decreases as the display field of view is increased.

The resolution of a target image can be improved by decreasing the projection angle of a zoom projector lens. This effect is illustrated in the family of curves in Figure 4. Two desirable features of a projector zoom lens are apparent in this family of curves. First, the variable image magnification offers a means to simulate changes in target range, and secondly, the compression of the target information improves the resolution of the small target image where high resolution is needed most. The zoom projector technique will be used in theAviation Wide Angle Visual Systems to provide small target imagery with resolution that approaches the limit of the human eye (approximately one arc-minute).

ASSESSMENT CRITERIA FOR ACCEPTANCE OF FIELD EQUIPMENT

A comprehensive list of tests and acceptance criteria for field visual systems is provided in Appendix A, paragraph 4.3.3 through 4.3.6. However, this set of acceptance tests may not be required for every procurement. The list of component and system tests should be tailored to the specific requirements of each visual system procurement. Only those tests which are necessary to determine complete compliance with the specification should be required. Unnecessary testing serves only to increase the cost of the procurement.

ASSESSMENT OF RISKS

The definitions of Table 7 will be used in the assessment of hardware and training risks. Risks are based on recommended specification language in Appendix A as of the date of this report. The distinction between hardware and training risks is important because a visual technique may have a low hardware development risk with a high training risk or vice versa. Furthermore, training risk is a function of the system application. A given system may have a low training risk for one application, but a moderate or high training risk for a different application.

Obviously, it is desirable for a new visual system to have both low hardware risk and low training risk. However, significant technological advancements are necessary before such a system for full mission simulation can be accomplished. In Section VI, existing technology is applied to major pilot training tasks. Hardware and training risks are assessed for each application.

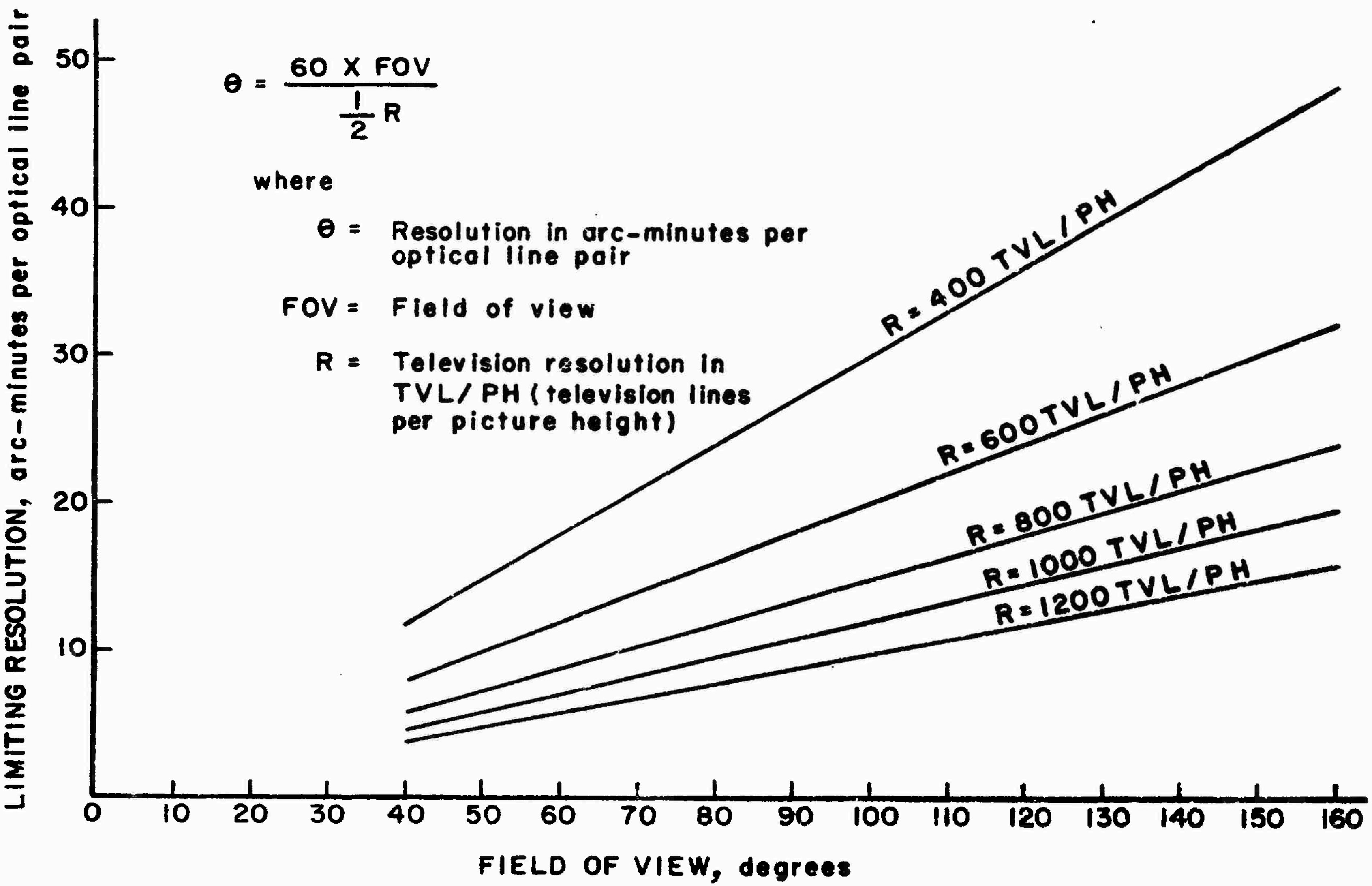


Figure 2. Limiting Resolution Versus Field of View

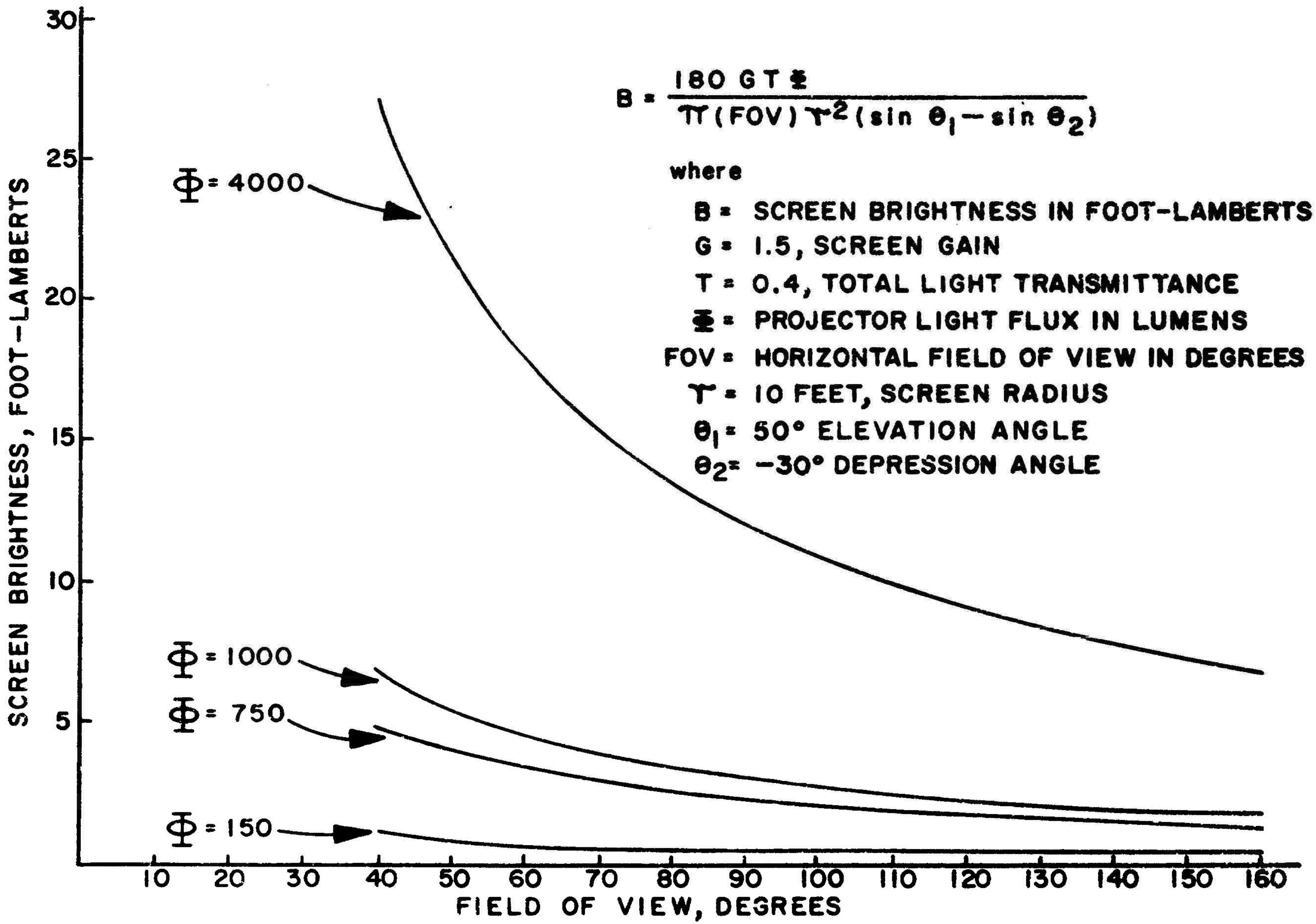


Figure 3. Spherical Screen Brightness Versus Field of View

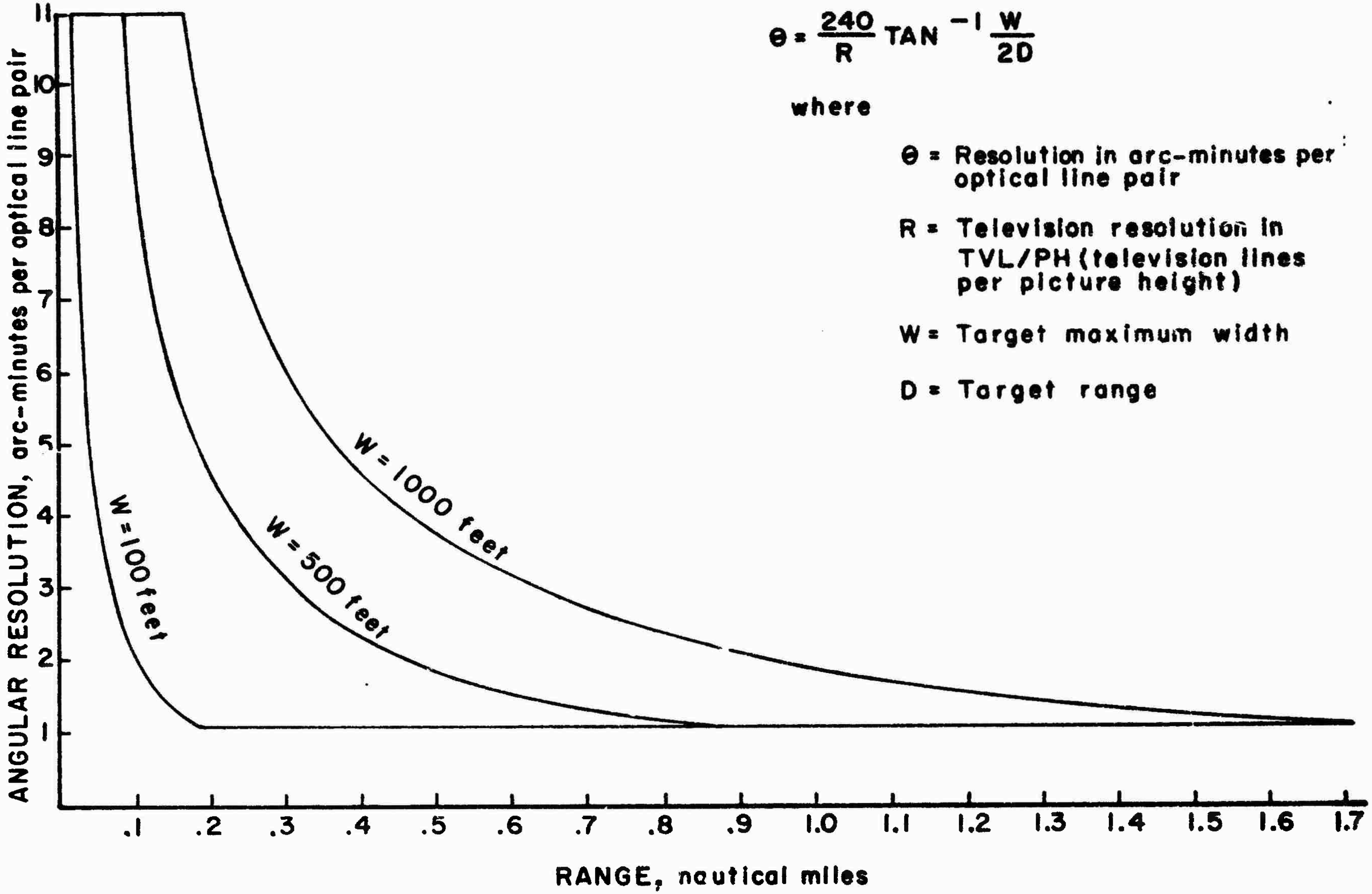


Figure 4. Angular Resolution Versus Target Range for 10:1 Zoom Projector Lens

TABLE 7. DEFINITION OF RISK CODES

Risk Code	HDW (Hardware)	TRG (Training)
L (Low Risk)	Technology in general use	Proven effective by similar technique
M (Moderate Risk)	Engineering development required	Unproven but analysis endorses
H (High Risk)	Research & development required	Unproven without significant analysis

SECTION VI

CONCLUSIONS

APPLICATION OF WIDE ANGLE VISUAL SYSTEMS TO TRAINING REQUIREMENTS

Current wide angle visual systems fall into two basic categories: developmental simulators for the design of advanced aircraft, and simulators for the training of pilots. Relative to the pilot training problem, none of these wide angle visual systems have been proven; they are all experimental. Several developmental simulators with wide angle visual systems are being used to design and evaluate advanced aircraft, but these systems, at best, can provide only part task training since they lack basic pilot training requirements such as takeoff and landing simulation. There are several experimental wide angle visual systems that are being developed for pilot training; however, the only wide angle visual system currently in the training evaluation phase is a CGI system installed on a Device 2F90 trainer at NAS Kingsville.

Possible applications of image generation sources to CTOL pilot training tasks are indicated in Table 8. Hardware and training risks for each application are identified individually by letter code. The risk codes are defined in Table 7. Wide angle visual display systems that could be applied to CTOL pilot training tasks are indicated in Table 9. Again, hardware and training risks are indicated by the same letter codes defined in Table 7. In each case, the system applications and risk assessments are based on engineering judgement. A thorough analysis of specific pilot training requirements should be conducted before any image generation sources or wide angle visual systems are applied to an aircraft specific visual system procurement. The Aviation Wide Angle Visual Program will provide essential human factors data for the analyses of pilot training task requirements. Furthermore, the program will provide design criteria for the specification of visual systems to fulfill these requirements. Table 10 indicates some of the data and information to be provided by the Aviation Wide Angle Visual Program.

SECTION VII

RECOMMENDATIONS

It is recommended that visual system techniques for part task simulation be used until the current wide angle visual techniques are improved and proven for training applications. However, if a full mission simulator were to be required today, a system such as that outlined in Appendix A would be recommended. Appendix A may be used as a guide for specifying a full mission capability or a part task capability. Part task simulation may be specified by including only those paragraphs related to the desired training tasks. However, the hardware and training risks should be assessed carefully before any official procurement document is prepared.

Finally, it is recommended that the Aviation Wide Angle Visual Program be accelerated to the largest extent possible. This program will provide design criteria and human factors' requirements to develop totally cost-effective visual systems with the highest return on life cycle investment.

SECTION VIII

REFERENCES

1. "Masters Theses" of University of Florida (U73-239), "Visual Flight Simulators applied to Naval Air Training", 1972, Class MD8, U. S. Naval Flight Instructors.

TABLE 8. IMAGE GENERATION SOURCES APPLIED TO CTOL TRAINING TASKS

CTOL* PILOT TRAINING TASKS	RISK ASSESSMENT (See Table 7)	Large Area Terrain Model Board/TV Camera	Large Area Terrain, Computer Generated	Air Field Model Board/TV Camera	Air Field, Computer Generated	Optical Generation System (Ground Target Circle, FLOLS, etc)	Aircraft Carrier Model/TV Camera	Aircraft Carrier, Computer Generated	Aircraft Model (Target, Formation, Tanker)/TV Camera	Aircraft, Computer Generated	Point Light Source Sky/Earth/Seascape Projector	60 Degree Synthetic Terrain Generator(s)	Special Effects (Fog, Haze, etc.) Generation System
		IMAGE GENERATION SOURCES: Narrow Angle (Area of Interest)									Wide Angle		Spec Eff.
Circling Carrier Takeoff & Landing (day & night)	HDW					M	L	M			L		M
	TRG					L	M	M			M		M
Field Takeoff & Landing (day & night)	HDW			L	M						L	M	M
	TRG			M	H						H	M	M
Air-to-Air Combat (day)	HDW								L	M	L	M	M
	TRG								L	M	H	M	M
Air-to-Ground Weaponry (day)	HDW	L	M			M					L	M	M
	TRG	M	M			M					H	M	M
Formation Flight (day)	HDW								L	M	L		
	TRG								M	M	L		
In-Flight Refueling (day)	HDW								L	M	L		
	TRG								M	M	L		
Aerobatics (day)	HDW										L	M	
	TRG										H	M	

*CTOL (Conventional Takeoff and Landing)

TABLE 8. WIDE ANGLE VISUAL SYSTEMS APPLIED TO CTOL TRAINING TASKS

CTOL* PILOT TRAINING TASKS	RISK ASSESSMENT (See Table 7)	A. Point Light Source Sky-Earth Projector, CRT* Projectors with shrunken Raster and Gimballed Optics, Spherical Screen with a CRT* Virtual Image Window	B. Point Light Source Sky-Earth Projector, Gimbal mounted CRT* Projector with Shruken Raster and Refractive Optics	C. Matrix of Color CRT's* with Mirror/Beamsplitter Virtual Image Optics	D. Mosaic of Monachrome CRT's* with Pancake Window Virtual Image Optics	E. Mosaic of Monochrome CRT's* with Shrunken Raster and Pancake Window Virtual Image Optics	F. Single Row Matrix of Color Light Valve Projectors with Flat Rear Projection Screens	G. Point Light Source with Planar Transparency and Spherical Screen
Circling Carrier Takeoff & Landing (day & night)	HDW		L	M			L	
	TRG		M	M			M	
Field Takeoff & Landing (day & night)	HDW	L	L	M	M		L	L
	TRG	M	H	M	M		M	M
Air-to-Air Combat (day)	HDW	L	L			M		
	TRG	H	H			M		
Air-to-Ground Weaponry (day)	HDW	L		M		M		
	TRG	H		M		M		
Formation Flight (day)	HDW		L		M	M	L	
	TRG		M		M	M	M	
In-Flight Refueling (day)	HDW		L		M			
	TRG		M		M			
Aerobatics (day)	HDW		L		M		L	
	TRG		H		M		L	

*CTOL (Conventional Takeoff and Landing)

TABLE 10. AVIATION WIDE ANGLE VISUAL PROGRAM SPIN-OFF

FY 75	FY 76	FY 77	FY 78	FY 79
1. Capabilities Report	1. Capabilities Report	1. Capabilities Report	1. Capabilities Report	1. Capabilities Report
2. CTOL Design Analysis Report	2. CTOL Subsystem Demonstrations	2. CTOL Visual Demonstrations	2. Evaluation of CGI vs Model Board techniques	2. Motion Requirements
3. CTOL Preliminary Capability Demonstration	3. VTOL Preliminary Capability Demonstrations	3. Display Resolution Requirements	3. Evaluation of Image Insetting Techniques	3. G-seat Requirements
4. VTOL Design Analysis Report	4. Initial CTOL Visual Design Recommendations	4. CTOL Visual Design Recommendations	4. VTOL Visual Demonstrations	
	5. VTOL Subsystem Demonstrations	5. Initial VTOL Visual Design Recommendations	5. VTOL Visual Design Recommendations	

APPENDIX A
SPECIFICATION LANGUAGE FOR AVIATION VISUAL SYSTEM

212-109
15 August 1974

NAVAL TRAINING EQUIPMENT CENTER

ORLANDO, FLORIDA

SPECIFICATION LANGUAGE FOR AVIATION VISUAL SYSTEMS

PREPARED BY: ____________________

APPROVED BY: ____________________

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212-109
15 August 1974

NAVAL TRAINING EQUIPMENT CENTER
ORLANDO, FLORIDA

SPECIFICATION LANGUAGE FOR AVIATION VISUAL SYSTEMS

1. SCOPE

1.1 This guideline establishes the performance, design, construction and test requirements for an Aviation Wide Angle Visual System with a moveable target image. The visual system shall be delivered with a sky-earth background projector and multiple camera-model image generation systems. The visual system shall be integrated with a flight simulator which consists of a cockpit, motion platform, and computer. The word target used herein shall refer to all television imagery projected by the target projector. (Provide a brief description of the flight simulator and computer system with which the visual system will be integrated.)

1.2 This specification language is intended to provide guidance for preparing a formal specification for procurement of an aviation wide angle visual system for field use. Any portion of this document should be used only after careful review of the specific training requirements and consideration of possible tradeoffs associated with a specific procurement. Notes related to preparing a formal specification are provided in parentheses following paragraphs which require additional information. Letter designations are provided to the left of each paragraph number to indicate the type of information contained in the paragraph. The letter designations are defined as follows:

A Depends on the type of aircraft simulated

B "Boiler plate"; typical of information that is always required

C Cannot be specified at this time

M Subject to modification based on future research and development

P Part task specific; delete if simulation of task is not required

R Depends on simulation requirements; delete or modify as required.

2. APPLICABLE DOCUMENTS

2.1 Government publications.- The following documents, of the issue in effect on the date of request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-R-9673	Radiation Limits, Microwave and X-Radiation Generated by Ground Electronic Equipment
MIL-T-23991	Training Devices, Military; Specification for
MIL-T-82335	Trainers, fixed-wing, flight; General Specification for

STANDARDS

Military

MIL-STD-34	Preparation of Drawings for Optical Elements and Optical Systems; General Requirements for
MIL-STD-106	Mathematical Signs and Symbols for Use in Physical Sciences and Technology
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-150	Photographic Lenses
MIL-STD-188	Military Communications System Technical Standards
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Interference Characteristics for Equipment
MIL-STD-470	Maintainability Program Requirements (for Systems and Equipments)

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MIL-STD-471	Maintainability Demonstration
MIL-STD-681	Identification Coding and Application of Hookup and Lead Wire
MIL-STD-785	Reliability Program for System and Equipments Development and Production
MIL-STD-1241	Optical Terms and Definitions
MIL-STD-1310	Shipboard Bonding and Grounding Methods for Electromagnetic Compatibility
MIL-STD-1326	Test Points, Test Point Selection and Interface Requirement for Equipments Maintained by Shipboard On-Line Automatic Test Equipment
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

PUBLICATIONS

Military

MIL-HDBK-141	Optical Design, Military Standardization Handbook
MIL-HDBK-472	Maintainability Predictions

Department of the Navy

NAVAIR 51-40 ABA-5	Installation, Service, Operation and Maintenance Instruction, Fresnel Lens Optical Landing System
NAVSO P-3097	Automatic Data Processing Glossary

David Taylor Model Basin Report No. 1319

Naval Air Systems Command (NAVAIRSYSCOM)

(List number and title of NATOPS flight manual for simulated aircraft.)

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Naval Training Equipment Center (NAVTRAEQUIPCEN)

NAVTRAEQUIPCEN 71-C-0013-1	Training Device Design; Human Factors Requirements in the Technical Approach

(Copies of specifications, standards, drawings and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Procuring Contracting Officer.)

2.2 Other publications.- The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of request for proposal shall apply.

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI X 3.5	Flowchart Symbols for Information Processing

(Copies may be obtained from: American National Standards Institute Incorporated, 10 East 40th Street, New York, N.Y. 10016.)

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA No. 70	Standards of the National Fire Protection Association (National Electric Code)

(Application for copies should be addressed to the National Fire Protection Association, 60 Batterymarch Street, Boston, Mass. 02110.)

ELECTRONIC INDUSTRIES ASSOCIATION

EIA-STD-343	Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera

(Application for copies should be made to Electronic Industries Association, 2001 Eye Street, N.W., Washington, D. C. 20006.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Materials, parts and processes.- Unless otherwise specified, materials, parts, and processes shall conform to MIL-T-23991.

3.1.1 Interchangeability.- Interchangeability shall be in accordance with requirement 7 of MIL-STD-454.

3.1.2 Microcircuits and semi-conductors.- Transistors, diodes, microcircuits, integrated circuits and semi-conductors encapsulated in the TO-92 plastic package shall not be used. Transistors, diodes, microcircuits, integrated circuits and semi-conductors mounted in the TO-116 plastic encapsulated or TO-116 hermetically sealed packages may be used.

3.2 Design.- The visual system shall provide a wide angle background scene and a target image. The target image shall be moved about in position and orientation relative to the background scene in response to cockpit inputs and in accordance with all simulation requirements specified. The composite scene shall respond to cockpit and instructor control inputs. The wide angle visual system shall consist of a background sky-earth projector, a target projector and spherical screen, a Fresnel Lens Optical Landing System (FLOLS) simulator, a closed circuit television system, and multiple camera model image generation systems. The display system shall be mounted with the cockpit on the flight simulator motion platform. The sky-earth and target projectors shall be indirectly mounted to the motion platform through servo driven gimbal systems. Both projectors and the screen shall move with the cockpit and motion platform as a unit. The target projector shall superimpose the specified high resolution target images onto the wide angle background scene. When viewed from the pilot's nominal eye position in the cockpit, the background and all target images, taken one at a time, shall appear in the correct size, shape, and position at all possible target positions on the background scene. Design shall be in accordance with MIL-T-82335 and as specified herein. This specification shall have precedence over MIL-T-82335 in the event of specification requirement conflicts.

3.2.1 Design basis.- The design of the visual system shall be based upon Model ___ Aircraft, production # ___, Bu. No. ___. (Provide appropriate numbers of aircraft to be simulated.)

3.2.2. Mechanical design.- Mechanical design shall be in accordance with MIL-T-23991 and as specified herein.

3.2.2.1 Strength.- The visual system shall withstand, without damage, all stresses of the cockpit motion platform. The digital computer(s) and all visual system components including image generation, processing, and display system hardware shall be of adequate mechanical strength to withstand, without damage, stresses incident to movement, handling in transit, hoisting, tie-down aboard transporting vehicles and final installation.

3.2.2.2 Construction.- All visual subsystems shall be designed such that stress, strain, vibration and acceleration imparted by the gantry(s), gimbal(s) or cockpit motion platform shall not damage or degrade the performance of the visual system or any part of the trainer. Software and mechanical protection shall be provided to protect all hardware components of the feasibility model. Major components of the feasibility model shall be of modular construction such that installation, assembly and disassembly can be accomplished without special equipment. The cockpit and visual system shall be constructed such that the cockpit can be removed from the motion platform without destructive disassembly of the visual display system. Major components shall be interconnected by connectors and cable assemblies to simplify rearrangement of major components. The visual system and all visual system components shall be removable from the motion platform without destructive disassembly of any components. The visual system shall be attached to the motion platform with fasteners. Riveting or welding to the motion platform shall not be used.

3.2.2.2.1 Component weights.- All components and structures, which will be mounted on the cockpit motion platform, shall be constructed in a manner to render them as light as feasible consistent with the requirement for structural integrity and visual system rigidity posed by the motion system. The motion platform is designed to drive a maximum gross weight of ____ pounds. (Designate the maximum weight carrying capability of the cockpit motion platform.)

3.2.3 Electrical and electronic design.- The electrical and electronic design shall be in accordance with MIL-T-23991 and as specified herein.

3.2.3.1 Power.- The visual system and all electrical and electronic equipment, supplied by the contractor, shall be operable from 120/208 volt 3-phase, 4-wire, 60 Hz power source and in accordance with NFPA 70.

3.2.3.1.1 Power factor.- A power factor of not less than 90 percent shall be maintained in the visual system under normal operating conditions.

3.2.3.1.2 Balance.- Three phase power shall be balanced, during normal operating conditions, such that the current in any phase does not deviate by more than 5 percent from the average current in all three phases.

3.2.3.2 Television.- The signal-to-noise ratio of all television video systems shall not be less than 30 decibels. All television subsystems shall have no fewer than 10 shades of gray in accordance with EIA-STD-343. Cable shields shall be routed through connector pins, and all coaxial connectors and recepticals shall be isolated from chassis ground to minimize electrical interference.

3.2.3.3. Grounding and grounding systems .- Grounding system design shall be in accordance with 3.2.3.13 through 3.2.3.13.4 of MIL-T-23991.

3.2.4 Servo design.- All servos shall be capable of following their respective angles to simulate the full frequency range of the simulated aircraft within the following tolerance limits:

(a) Resolution .01 percent minimum

(b) Linearity .05 percent minimum

(c) High speed tracking error .1 percent maximum

(d) Low speed tracking error .05 percent maximum.

3.2.4.1 Automatic reset.- All servos shall be capable of being positioned automatically by the computer and/or instructor during the reset mode of the computer.

3.2.5 Optical design.- Optical design, manufacture, and testing shall be in accordance with MIL-T-23991, MIL-STD-34, MIL-STD-150, MIL-STD-1241 and as specified herein. Sign convention, symbols and glossary used for reporting shall be in agreement with MIL-HDBK-141.

3.2.5.1 Optical design wavelengths.- The following wavelengths shall be used for design and performance data instead of the conventional d, F, and C lines:

primary color e: 546.07 nanometers

secondary colors

short F : 479.99 nanometers

long C : 643.85 nanometers

in order for the minimum of the secondary spectrum to coincide better with the primary wavelength.

3.2.6 Human engineering.- Human engineering design criteria shall be in accordance with MIL-T-23991 and as specified herein. The requirements of MIL-STD-1472 shall apply to the layout and arrangement of the equipment.

3.2.6.1 Safety.- As a part of the system equipment design, safety factors shall be given major consideration. The hazards and safety considerations of MIL-STD-1472, and Requirement 1 of MIL-STD-454 shall apply.

3.2.6.1.1 Clearances.- The motion platform, including all visual system attachments, shall have a minimum clearance of three feet between the maximum travel of the motion platform with visual system and the closest cabinet or other obstruction. A minimum clearance of six inches shall be established between the maximum travel of the motion platform and the ceiling, walls, personnel operating areas, and walkways.

3.2.6.1.2 Acoustical noise.- Spurious sound and noise, associated with the visual system operation, shall not provide cues to the trainee. Control of equipment noise generation and penetration shall be in accordance with the requirements of MIL-STD-1472. Noise criterion curve 60 (NC-60), Figure 33, MIL-STD-1472 shall be applied as a minimum standard.

3.2.6.1.3 Stray light.- There shall be no objectionable stray or scattered light nor reflections in the display field of view.

3.2.6.2 Man/system interface.- The instructor shall be able to control the problem from a single position. Detailed design of the instructor station shall be in accordance with MIL-STD-1472.

3.2.7 Simulation requirements.- Flight tasks shall be simulated in accordance with the aircraft NATOPS Manual. The gaming area of the visual system shall be 50 nautical miles square. Positions of runway threshold, carrier center of gravity, and aircraft shall be determined to 1/8 foot resolution within the gaming area. The visual system shall generate and present real time images of a simulated visual environment. The visual scene shall be derived from multiple sources as a function of the task to be performed. The visual system shall be designed such that the following flight tasks can be simulated:

(a) Circling field and carrier traffic patterns under daylight, dusk and night conditions

(b) Circling carrier arrested landing under daylight, dusk and variable ceiling conditions

(c) Catapult takeoff and bolter under daylight, dusk and variable ceiling conditions

(d) Air-to-air combat

(e) Air-to-ground weapons delivery

(f) Formation flight

(g) In-flight refueling

(h) Instrument flight with visual breakout.

(Support of the above flight tasks may require modification of the existing simulator hardware and software. Delete flight tasks that are not required.)

3.2.7.1 Visual system response.- The visual system shall respond to pilot and instructor control actuations as specified herein.

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3.2.7.1.1 Carrier motion.- The motion of the aircraft carrier with respect to the ocean surface shall be continuously controllable by the instructor. The following ships motion shall be simulated:

(a) Speed: 0 - 50 knots

(b) Heading: 0° to 360° continuous

(c) Roll: 0° to 12° left and right in a period of 16 seconds

(d) Pitch: ± 5°

(e) Heave: 0 to ± 30 feet in a period of 10 seconds.

3.2.7.1.2 Target aircraft motion.- The motion of the target aircraft shall be continuously controllable by the instructor. The following target aircraft motion shall be simulated with the kinematic characteristics of the simulated target aircraft:

(a) Velocity: 0 to 1400 knots

(b) Heading: 360 degrees continuous (air-to-air combat model)
±90 degrees minimum (formation flight and tanker models)

(c) Roll: 360 degrees continuous (air-to-air combat model)
±90 degrees minimum (formation flight and tanker models)

(d) Pitch: 360 degrees continuous (air-to-air combat model)
+90 degrees minimum (formation flight and tanker models).

3.2.8 Product markings.- Identification markings shall be permanent and legible. The markings on plastic or metallic materials shall be accomplished by ink stamping, embossing, engraving, silk screening, or stenciling with a smudge-proof ink. Markings shall be covered with a coat of clear lacquer.

3.3 Reliability.- Reliability shall be in accordance with the Government approved Reliability Program Plan of the contract and the following::

3.3.1 Reliability program.- The Reliability Program shall be established in accordance with MIL-STD-785. The Reliability Program Plan as prepared shall reflect the policies and procedures of management to provide effective guidance and continuity, and shall become a basis for contractual compliance when approved by the procuring activity.

3.3.2 Quantitative reliability.- The quantitative requirements for serial operation (for all elements operating satisfactorily for a specified time period) shall be as follows:

Specified MTBF (Mean-Time-Between-Failures): 300 hours

Minimum Acceptable MTBF: 100 hours.

3.3.3 Qualitative reliability.- The feasibility model design shall include practical features that will result in reliable and stable operation. The visual system shall be designed so that a component failure in one section will not cause failure of components in other sections. Reliability development procedures shall include as a minimum; (a) Review of system requirement to establish an accurate picture of all parameters which may affect performance; (b) Operational environment; (c) Evaluation of proposed design to ensure that suitable features have been incorporated to assure stable equipment operation; (d) Estimation of inherent reliability and operational reliability, serially; (e) Analysis of proposed design to obtain component reliability allocations and allowable failure rates of components.

3.3.4 Availability.- The inherent availability shall not be less than 99.5 percent based upon a trainer utilization of 16 hours per day, 6 days per week.

3.4 Maintainability.- Maintainability shall be established in accordance with the Government approved Maintainability Program of the contract and as specified in MIL-T-23991 and the following:

3.4.1 Maintainability program.- The Maintainability Program shall be established in accordance with MIL-STD-470 and as specified herein.

3.4.1.1 Quantitative requirements.- The quantitative maintainability requirements for the visual system, including the computer and peripheral equipment shall be: (a) Mean corrective maintenance downtime (M_{ct}) shall not exceed 0.9 hour, and (b) the maximum corrective maintenance downtime ($M_{max_{ct}}$ - 90th percentile) shall not exceed 1.9 hours. Confidence levels shall conform to the requirements of MIL-STD-471, Method 1.

3.4.1.1.1 Prediction technique.- The contractor's maintainability prediction technique shall be in accordance with MIL-HDBK-472.

3.4.1.2 Qualitative requirements.- The qualitative maintainability requirements shall be in accordance with MIL-STD-1472.

3.4.2 Accessibility.- Accessibility requirements shall be in accordance with MIL-T 23991 and as specified herein:

3.4.2.1 Assemblies.- Channel-guided sections with the provisions of tracks, rollers, or pivots, or a combination thereof, are the required method of chassis construction for providing accessibility to units, assemblies, subassemblies and parts. Locking devices shall be provided to lock the chassis in the servicing position as well as in the fully opened and fully closed positions. The design of each major assembly, subassembly, and unit of the equipment shall permit easy and ready access to its interior components and parts for maintenance. It shall not be necessary to displace or remove wires, cables, subassemblies or assemblies in order to gain access to mounting screws, test points, adjustment points, lubricating points, and the like. Where visual inspection is necessary and open access is not feasible, transparent access panels shall be used. The placement of parts shall be such as to provide sufficient space for the use of test probes and soldering tools. Assemblies subject to replacement or servicing, shall not be permanently secured thereby prohibiting ready removal. Plugs and connectors shall be used where wiring is connected to drawers and assemblies.

3.4.2.2 Wiring board extender cards.- In high density applications where connector termination points are not readily accessible for testing purposes, appropriate extender cards shall be provided. Extender cards shall have a matching indexing system and shall be clearly and distinctly identified with their corresponding wiring boards. Varnish or other insulating materials shall not be applied to the conducting surfaces.

3.4.2.3 Covers, panels and doors.- Hinged covers and doors shall be capable of being retained in their open positions in order to prevent accidental closing due to jarring or vibration and, when opened, shall not cause the equipment to become unbalanced. Front panels which contain parts requiring maintenance such as instruments, switches, potentiometers and the like, shall be hinged. Where parts or assemblies are mounted on hinged doors, panels or covers, electrical ground return shall not depend on hinge contact for electrical continuity. A separate grounding means shall be provided for the electrical ground return. Locking devices shall be installed on the panels to retain them in the open position to permit accessibility to all parts mounted on the panel and to prevent damage to the panel or injury to personnel performing maintenance.

3.4.2.4 Handles.- Handles or suitable hand grips shall be provided for removing units or chassis from enclosures without strain or injury to personnel effecting removal. Handles on enclosures will be recessed.

3.4.2.5 Replacement of modular assemblies, parts and microelectronic functional devices.- Plug-in techniques shall be used to permit rapid replacement of all modular assemblies. Where the design requires the use of electromechanical assemblies, the modular parts and subasssemblies contained therein shall be mounted so as to permit easy and ready removal and decoupling from the mechanical portion of the assembly. The replacement of parts shall be such that replacement of any part is possible without removal or damage to adjacent parts.

3.4.2.6 Mismating of electrical connections.- Means shall be provided to prevent mismating of electrical connectors. All modular assemblies shall be designed so that they can be inserted into the equipment in one position only. Sockets shall be oriented in the same direction and shall be positioned so that the sockets are readily visible and accessible to maintenance personnel.

3.4.2.7 Adjustment and calibration.- The time required for adjustment and calibration due to the replacement of an assembly or part shall be consistent with the specified quantitative maintainability requirements. The necessity for sequential adjustment or alinement shall be avoided. Adjustable parts, such as: potentiometers and variable capacitors, shall be located so that their adjustment devices are visible and accessible with the chassis in an operating position.

3.4.3 Test points, test facility, and test equipment.- The requirements of MIL-T-23991 and the following shall apply:

3.4.3.1 Test points.- Test points shall be built into the equipment to aid in its installation, maintenance, operation, calibration, and repair. Electrical test points shall be provided and identified for checking essential waveforms and voltages and for the injection of test signals. Each assembly or subassembly of the equipment shall be provided with test input and output connection to permit the application of externally generated test signals and external measurement and indication of response to the test signals. The test points shall be located on the surface that is accessible when the assembly is mounted in the equipment. When test points provide access to voltages or waveforms to be measured against ground potential, at least one conveniently located grounded test point shall be furnished. Test point(s), where the application of conventional test equipment probes could possibly cause damage to internal circuits (such as, integrated circuits), shall be marked with a warning placard.

3.4.3.2 Built-in test facilities.- Built-in test facilities shall be incorporated such that calibration, fault detection, fault isolation, and performance monitoring functions, can be effected. The built-in test facilities shall be designed so that rapid assessment of test results may be achieved and malfunctions are isolated to the assembly level or lower.

3.4.3.3 Test equipment.- All equipment other than "off-the-shelf equipment" shall be so designed as to be capable of being maintained, tested, alined, adjusted, calibrated and repaired using standard test equipment.

3.4.3.4 Assembly tester.- An off-line assembly tester shall be provided by the contractor. The unit shall be designed to check dynamically all removable assemblies, including modular assemblies and printed circuit boards. The assembly tester shall supply all necessary test voltages and test signals for the purpose of isolating a malfunction to the piece part within the assembly under test within the constraints of the approved maintenance concept for each assembly and module. The test voltages, signals and loads provided shall include those which are applied to the assembly or module under normal operating

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conditions and shall also include provisions for varying critical voltages, signal amplitudes and time durations for marginal testing. Plug-in provisions shall be incorporated for testing all plug-in modular assemblies, microelectronic functional devices and repairable assemblies used in the equipment. The assembly tester shall incorporate an on-off switch and shall contain its own circuit protective devices. The use of the assembly tester shall not affect the operation of the training device and associated equipment.

3.4.3.5 Test procedures.- The test procedures shall provide, as a minimum, the following functions:

(a) Detection of performance degradation and incipient failure

(b) Assessment of overall integrity of the equipment

(c) Elimination of the necessity of taking measurements under hazardous conditions.

3.4.3.5.1 Automatic techniques.- Complex functions, such as: test point scanning, stimuli control, signal conditioning, and signal comparison and readout, shall be accomplished by automatic techniques in accordance with MIL-STD-1326.

3.4.3.5.2 Manual techniques.- Panel meters and monitor scopes shall be provided for measuring parameters, such as: power supply voltages and critical waveforms, which require periodic observations. Selector switches shall be provided with each monitor scope to allow display of multiple critical waveforms. In such cases, overlays which show acceptance waveforms and associated tolerances shall be provided. Indicators shall be provided which measure pneumatic or hydraulic pressures when these features are used in the equipment. A blown-fuse indicator light shall be located at the front of each equipment rack such that the indication of blown fuses is evident.

3.5 Transportability.- The system shall be designed to be transportable to the installation site by standard commercial transportation. Major design components shall be constructed such that installation and assembly can be accomplished with a minimum of special equipment or tools. Major components shall be interconnected by cable assemblies. Design shall be such that assembly and disassembly of the system can be accomplished without the necessity for soldering, welding, unsoldering, cutting, crimping, or destruction of material. Each major component shall have provision for lifting and moving by forklift.

3.6 Performance characteristics.- The trainer performance shall be in accordance with NATOPS handbook (NAVAIR _____), flight test data, and as specified herein. NATOPS handbooks, performance data, and operational flight data shall have precedence over equipment specifications, predicted data and other operational equipment design data.

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3.6.1 Visual system performance.- The visual system shall be designed to meet the following minimum requirements while simultaneously satisfying the visual system components requirements:

(a) Pilot eye height (simulated): the pilot eye height of _____ feet above the runway and carrier deck shall be simulated

(b) All target imagery, the FLOLS and the background horizon shall be displayed to within 1 degree of the theoretical position relative to the pilot's nominal eye position in the cockpit

(c) Contrast: 15 to 1 ratio (target and background)

(d) Geometric distortion: composite error in the final scene due to pin cushion or barrel distortion, keystoning, and non-orthogonal scans as defined in MIL-STD-1241 shall not be greater than 2.5 percent

(e) Image quality: the final images displayed to the pilot shall have adequate scene quality and dynamic fidelity to permit judgement of rate of closure. The image shall not include mechanically induced shock waves or any discontinuities or irregularities throughout the field-of-view or visual display system range of operation

(f) Physical constraints:

(1) There shall be no interference with the operation of the motion system such as limiting response and range of motion due to visual system equipment characteristics or performance

(2) The visual system shall not interfere with cockpit ingress or egress

(3) All visual system equipment mounted on the motion system shall be capable of withstanding acceleration loads 2 times the maximum loads (including buffet) achievable by the motion system. System alinement shall not be affected by the motion system accelerations

(g) Radiation shielding shall comply with MIL-R-9673.

3.7 Details of components.- The contractor shall modify existing on-site components and provide additional components as required to provide simulation of the performance, operation, and visual environment of the aircraft to the extent specified herein.

3.7.1 Display screen.- The display screen shall be spherical with an inside radius of 10 feet. The 10 feet radius shall be held to within ±0.5 inches. Seams on the screen shall not be apparent to the viewer when the usual scene is projected on the screen. The outside dimensions of the screen and screen support structure shall be contained within a diameter no greater than 21 feet. The spherical display screen shall provide a minimum unobstructed field of view of 240° (±120°) horizontal and 120° (+90°, -30°) vertical. The display screen shall be mounted to and supported by the mechanical structure of the motion platform. The screen shall be supported such that no movement of the displayed image is observable under normal simulated vehicle acceleration cues. The screen and screen support structure, shall be constructed to provide a minimum clearance of six inches between the screen support structure and the floor with worst case excursions of the motion platform. The maximum weight of the display screen and supporting structure shall not exceed 2000 pounds. The weight shall be distributed such that the motion system operation is not adversely affected.

OPTION I

3.7.2 Computer Generated Imagery (CGI) System.- CGI has the potential of being the single most powerful image generation technique in visual simulation technology and it is anticipated that it may become the most economical approach to visual simulation. However, CGI is not recommended for current visual system procurements because of insufficient positive experimental results. The most promising CGI systems are still considered to be in the stage of research and development with significant advances projected for the near future. Greater detail (number of edges) and higher resolution than that currently available are required for some flight tasks which require both wide angle and high resolution. The Aviation Wide Angle Visual System Program will contribute to the development of CGI and will explore the tradeoffs between CGI and model board image generation. Future recommendations for image generation systems will be based upon the outcome of the near term developments.

OPTION II

3.7.2 Model board.- A model board shall be provided to simulate a coastal area and landmass having a variety of cultural and environmental detail including a typical Naval Air Station. Figure 1 provides the basic requirements for the model board including the requirement for a separate aircraft carrier model.

3.7.2.1 Model board detail.- The following detail parameters apply to the model board:

(a) Lighting (scene detail) quantity: as required in quantity and distribution to simulate typical cultural lighting around a Naval Air Station and within all urban and rural areas

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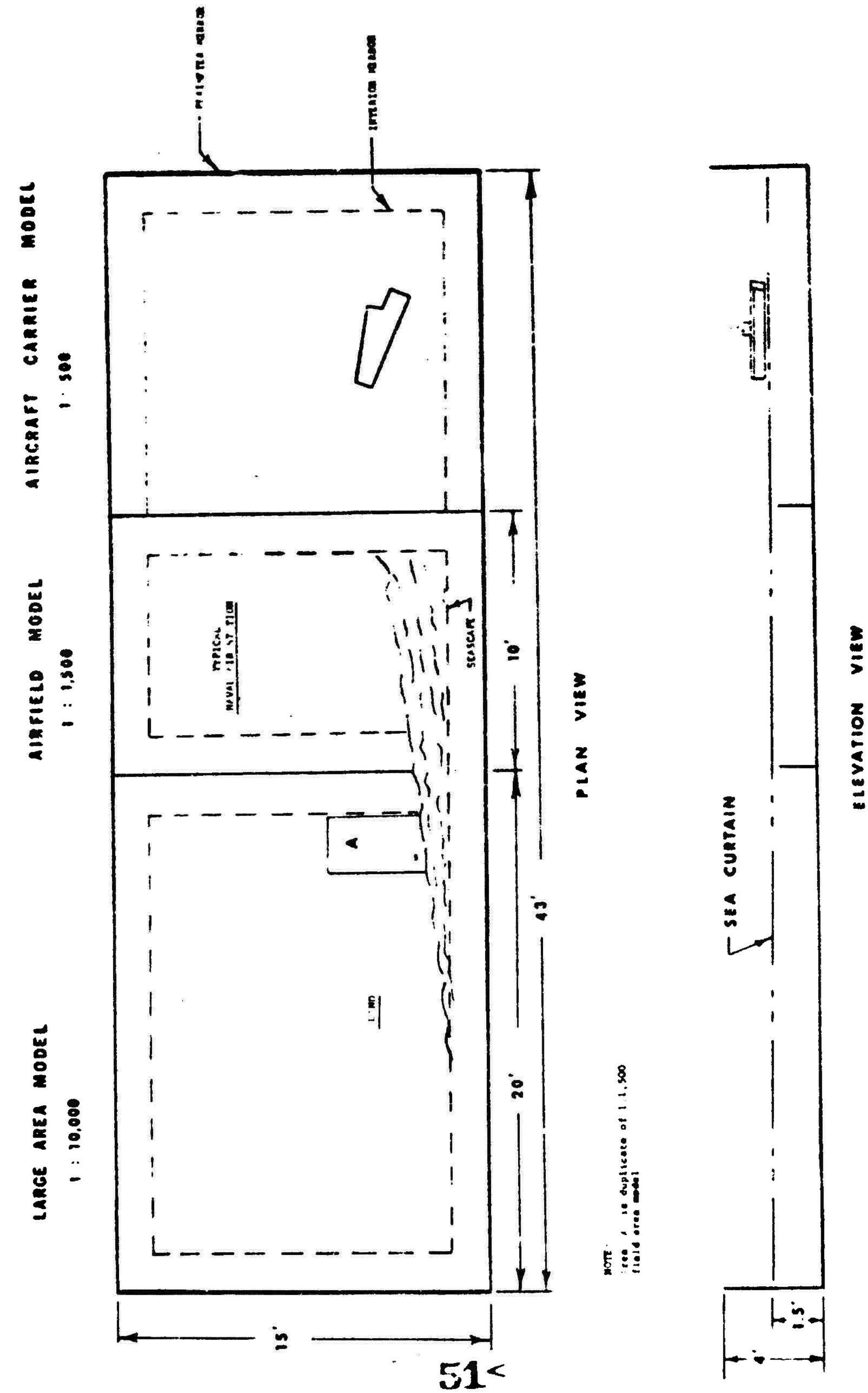

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MODEL BOARD DIMENSIONS & LAYOUT

Figure 1

(b) Dimensions: the model board shall be mounted vertically and joined together to form a single unit 15 to 16 feet high by 43 to 44 feet long (not including supporting structure)

(c) Illumination: shall satisfy the requirements of the television camera. All illumination equipment, including air-conditioning ducting and equipment, shall be provided as part of the model installation. Model illumination shall be consistant with overall visual system performance requirements, safety, and power considerations. Illumination shall be uniform at all points on the model surface so as to simulate a high noon sun angle without shadows. Make-up lighting shall be provided on the gantry (if required) to prevent gantry shadows and to maintain a uniform illumination of the model surface. Illumination shall not deteriorate the structure, texture, or color of the model board

(d) Seams: model board seams shall be disguised so as to make seams indistinguishable at the final display

(e) Model area transition: a corridor shall be provided between the 1:10,000 and 1:1,500 model board areas for the purpose of providing a continuous visual reference to the pilot during field takeoff and landings.

Example:

> A normal landing will commence on the 1:10,000 model board area with a low altitude fly-by of the Naval Air Station, and a heading towards the seascape. A standard 180 degree turn will be made by the pilot to line up with the runway. During the 180 degree turn, the optical probe shall transition from the 1:10,000 area to the 1:1,500 area. The detail of the seascape shall be such as to not introduce false cues during the model area transition.

(f) Model board scales: all model board scales (including aircraft carrier) are to be considered tentative. Scales shall be subject to the approval of the PCO.

3.7.2.1.1 Large area model.- The large area model is defined as the 1:10,000 scale area of the model board and shall consist of the following:

(a) Size: Nominal 15 feet high
Nominal 20 feet wide

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(b) Primary detail:

(1) Airfield: the airfield shall be modeled so as to maintain proper perspective (three dimensions) and relative sizes of the runway in relation to terrain and objects of known size near the runway. All runway markings and lighting shall be provided in proper textures and locations including taxi areas, parking, buildings and facilities

(Specify specific airfield if desired.)

(2) Airfield lighting: the model shall contain all typical Naval Air Station lighting including taxi, threshold, runway, rotating double flash beacon, strobes, and other miscellaneous lights. The integration of lights into the model shall be such that the lights do not create noticeable degradation of the airfield scene regardless of whether the lights are illuminated or extinguished. All lights shall present a brightness which is compatible with the highlight brightness which can be produced at the final display. The brightness of the lights shall be automatically controlled as a function of probe position and orientation so that their relative brightness corresponds to actual conditions

(3) Terrain features: the exact layout of the model board will be subject to the Mockup Review Conference to be held in accordance with the Contract Schedule. Besides the Naval Air Station to be located on the model board, the following general features shall be provided:

a. Urban area consisting of 20 percent of area with high density of cultural items and high density random lighting

b. Rural area consisting of 75 percent of area with low density random lighting

c. Seascape consisting of 5 percent of area

(c) Terrain extension: terrain extension mirrors shall surround the entire 1:10,000 scale area except for the transition corridor to the 1:1,500 scale area. The height of the mirrors shall be 1.5 feet for the internal mirror and 4.0 feet for the perimeter mirror.

3.7.2.1.2 Airfield model.- The airfield model is defined as the 1:1,500 scale area of the model board and shall consist of the following:

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(a) Size: Nominal 15 feet high
Nominal 10 feet wide

(b) Primary detail: the airfield model shall be scaled in all respects to duplicate the Naval Air Station and surrounding area contained on the large area model. The airfield shall have the same lighting pattern and airfield markings except with more detail consistent with the model scale. Integration of the lights into the model shall be such that the optical probe is not obstructed for any taxi, takeoff, or landing mode of operation and does not create noticeable degradation of the airfield scene regardless of whether the lights are illuminated or extinguished. All lights shall present a brightness which is compatible with the highlight brightness which can be produced at the final display. The brightness of the lights shall be automatically controlled as a function of probe position and orientation so that their relative brightness corresponds to actual conditions

(c) Terrain extension: terrain extension mirrors shall surround the field area model as required for the large area model

(d) FLOLS tracking: the FLOLS projector shall track the proper location on the airfield throughout the entire model approach pattern.

3.7.2.1.3 Aircraft carrier model.- A 1:500 scale model of the ______________ (CVA ____) shall be provided and coordinated with the automatic carrier landing system of the Device ________. The carrier shall be mounted on a three degree-of-freedom motion base to simulate carrier roll and pitch in accordance with 3.2.7.1.1 of this specification. The carrier heading shall be adjustable by the instructor to allow different relative flight path approaches to the carrier. The aircraft carrier model shall correlate with all Device ____ systems simulation including radar, navigation, communications, data link, and landing systems. The aircraft carrier model shall be provided with a wake discernable at the final display from a distance of 3.0 nautical miles (scaled). The carrier wake shall not be less than twice the length of the carrier deck. The wake shall rotate with the carrier model for simulated heading changes. The wake shall not roll, pitch, or heave with the carrier model. (Indicate the aircraft carrier to be simulated and provide the training device number.)

3.7.2.1.4 Sea curtain.- A single motor driven sea curtain shall be provided for use with the aircraft carrier model to simulate the ocean for over-water flights and carrier operations. The sea curtain shall be deployed or retracted within a 5 minute time period. The sea curtain shall, when deployed, remain motionless to the extent that it will not

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present at the final display a sea in motion. Its size shall be adequate to cover the entire model board (15 feet by 43 feet).

3.7.2.1.5 Carrier lighting.- All carrier lighting (less FLOLS) shall be provided including the deck edge, centerline strobe, runway edge, ramps, and drop lights. The integration of the lights into the model shall be such that no noticeable degradation occurs to the carrier image whether the lights are illuminated or extinguished. All lights shall present a brightness which is compatible with the highlight brightness used in the final display. The brightness of the lights shall be automatically controlled as a function of range and position. Controls shall be provided to enable the instructor to control lighting groups independent of one another.

3.7.3 Gantry.- A vertical gantry shall provide the support and drives for the optical probe and television camera subsystem.

3.7.3.1 Gantry servo system.- All servo operations shall be precise, with loop response capable of providing the rates, degree of smoothness, and accuracy as specified. Jitter, backlash, and time phase lags shall not be discernable at the final display. A special effects and cloud cover generator shall be provided for visual scene fade out during probe transition.

3.7.3.1.1 Transport capability (lateral and longitudinal).- The gantry shall have the following minimum, except as noted, lateral and longitudinal transport capabilities:

(a) Excursion: 15 feet lateral and 47 feet longitudinal including over travel for maintenance purposes at one end of gantry

(b) Velocity:

(1) High: 0.5 feet per second

(2) Low: 0.00025 feet per second (maximum)

(3) Reset: 10.0 inches per second

(c) Dynamic velocity accuracy: 5 percent of command velocity or 0.00025 feet per second, whichever is greater

(d) Acceleration: 0.3 feet per second squared

(e) Static position accuracy: 0.004 feet

(f) Frequency response: 0 to 2.0 Hz at 3dB point.

3.7.3.1.2 Transport capability (altitude).- The gantry shall have the following minimum, except as noted, altitude transport capabilities:

(a) Excursion: 4.0 feet

(b) Velocity:

(1) High: 0.3 feet per second

(2) Low: 0.00015 feet per second (maximum)

(3) Reset: 0.5 feet per second

(c) Dynamic velocity accuracy: 5 percent of command velocity or 0.00015 feet per second, whichever is greater

(d) Acceleration: 0.3 feet per second squared

(e) Static position accuracy: 0.004 inches

(f) Frequency response: 0 to 2 Hz at 3dB point.

3.7.4 Optical probe.- The optical probe shall meet the following minimum requirements while satisfying the overall performance requirements of the final display system:

(a) Field-of-view: 60 degrees diagonal

(b) Focus: dynamic as a function of simulated altitude and attitude

(c) Focus range: 1.4 inches to infinity

(d) Entrance pupil to model board distance: located to meet simulated pilot eye height requirement with minimum probe clearance of .5 mm

(e) Entrance pupil position: located so as to prevent any variation with heading rotation

(f) Pitch control capability:

(1) Excursion: +25 degrees
-40 degrees

(2) Velocity (high): 150 degrees per second
(low): 0.15 degrees per second (maximum)

(3) Acceleration: 300 degrees per second squared

(g) Roll control capability:

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(1) Excursion: unlimited

(2) Velocity (high): 300 degrees per second
(low): 0.30 degrees per second (maximum)

(3) Acceleration: 500 degrees per second squared

(h) Yaw control capability::

(1) Excursion: unlimited

(2) Velocity (high): 150 degrees per second
(low): 0.15 degrees per second (maximum)

(3) Acceleration: 300 degrees per second squared

(i) Modulation transfer function (object in plane of best focus, for the visual spectral range from 400 to 700 nanometers)

(1) On axis: 70 percent of diffraction limit

(2) 30° off axis: 50 percent of diffraction limit

(j) Vignetting: none for 0 degrees to 30 degrees off axis at 0 degrees pitch and for worst case roll situation at maximum pitch less than 50 percent pupil area for the 18 degree semi-field angle

(k) Servo static accuracy: 6 arc minutes (for each attitude servo)

(l) Command rate: 60 per second position update utilizing compensation or smoothing techniques as required

(m) Crash prevention: hardware and software control to prevent probe from touching model and perimeter mirrors. The probe shall not come within 12 inches of any structure of other equipment other than model board details

(n) Structural interference: entrance pupil shall be capable of unrestricted operation to within 18 inches of the perimeter of each model board scaled area in addition to normal on-the-deck operation within runway edge limits of the aircraft carrier model.

3.7.5 Television camera systems .- All television camera systems shall include all hardware (less the sync generator) necessary to operate and maintain the display system.

3.7.5.1 Camera system performance.- All camera systems shall meet the following minimum performance criteria:

(a) Field rate:	30 frames per second interfaced 2:1
(b) Line rate:	30,690 Hz resulting in 1023 scanning lines/frame
(c) Resolution:	700 TV lines minimum horizontal and vertical center resolution and 570 TV lines minimum horizontal and vertical resolution at the corners of the image field
(d) Bandwidth:	20 MHz ± 1 dB
(e) Sensitivity:	1.5 foot-candles highlight brightness on vidicon target for specified resolution
(f) Aspect ratio:	1X1, 0.44 in. minimum raster size on vidicon target
(g) Target control:	Manual and automatic
(h) Signal-to-noise ratio:	40 dB peak signal to RMS noise for normal operating signal current
(i) Lag:	30 percent maximum residual signal after 50 milliseconds with full scan and normal operating face plate illumination
(j) Raster burn:	Not discernible
(k) Gamma:	Unity ± 10 percent at output of final display.

3.7.6 Camera control unit specifications.- All camera control unit electronics shall employ solid-state, modular construction. The equipment including all TV system controls shall be housed in a control console.

3.7.6.1 Sync generator.- The sync generator shall produce the four primary pulses required to drive the TV cameras and associated equipment. The following are the four pulses:

(a) Mixed sync

(b) Mixed blanking

(c) Vertical drive

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(d) Horizontal drive.

The sync generator frequency shall be controlled by a master oscillator capable of operating in a crystal locked, line locked, or free running mode.

3.7.6.2 Test signal generator and monitor.- Test signal generator and monitoring equipment shall be included in the control console for the purpose of calibration and maintenance of the TV system. The following test signals shall be generated::

(a) Vertical bars

(b) Horizontal bars

(c) Crosshatch.

3.7.7 FLOLS optical projector system. A servo positioned FLOLS optical projector shall be provided to simulate the normal FLOLS lighting defined in NAVAIR 51-40 ABA-5 found aboard aircraft carriers and Navy fields. The FLOLS projector shall dynamically simulate the Fresnel lenses (amber and red) and the datum lights (green) in addition to the waveoff lights (red) and cut lights (green) in a manner which simulates the normal operational mode. Only the Fresnel lenses are required to be simulated as discrete lights. The remaining sets of lights may be simulated as shown by Figure 2. The FLOLS light pattern shall be servo positioned in roll, pitch, and yaw and superimposed at the proper location onto the separately projected field or carrier image throughout the entire approach pattern and as appropriate shall be compensated for carrier motion.

3.7.7.1 Optical projector performance.- The FLOLS optical projector shall meet the following minimum, excepted as noted, performance standards:

(a) Image size: continuously variable throughout a 10:1 range under computer control

(1) Minimum size:

a. Width overall: 0.6 degrees ± .01 degrees

b. Fresnel lens diameter: 0.03 degrees ± .005 degrees

(2) Maximum size:

a. Width overall: 6.0 degrees ± 0.1 degrees

b. Fresnel lens diameter: 0.3 degrees ± 0.05 degrees

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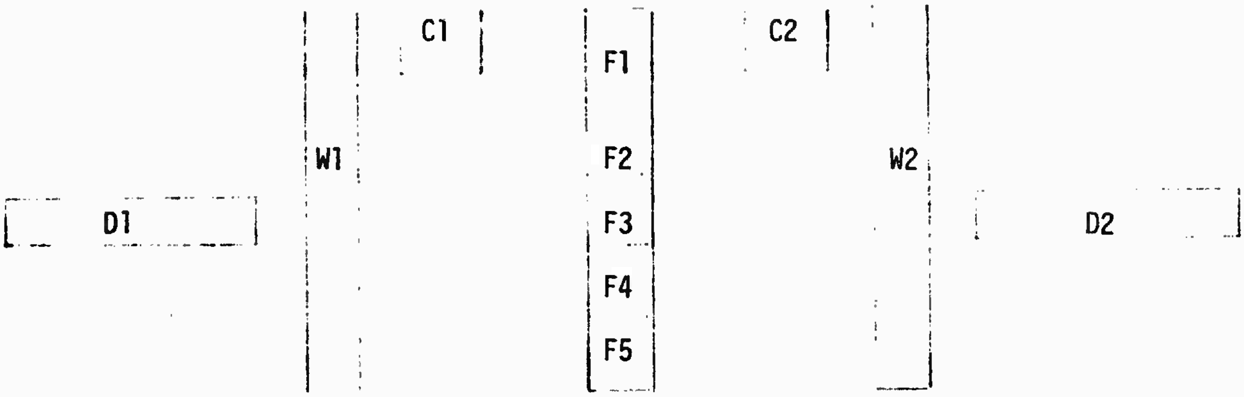

LEGEND

AREA	COLOR	FUNCTION
C1 & C2	GREEN	CUT LIGHTS
W1 & W2	RED	WAVE OFF LIGHTS
D1 & D2	GREEN	DATUM LIGHTS
F1 & F4	AMBER	FRESNEL LENSES (MEAT BALL)
F5	RED	FRESNEL LENS (LOW BALL)

FRESNEL LENS OPTICAL LANDING SYSTEM
Minimum FLOLS image detail

Figure 2

NOTE: FLOLS size specified as angular subtense at pilots normal eye position for 10 percent of peak brightness.

(b) Dynamic FLOLS image size accuracy:

(1) 5 percent of command size

(c) Pitch control:

(1) Excursion: ± 20 degrees

(2) Velocity:

a. High: 60 degrees per second

b. Low: 0.15 degrees per second (maximum)

(3) Acceleration: 60 degrees per second squared

(d) Roll control:

(1) Excursion: ± 45 degrees

(2) Velocity:

a. High: 60 degrees per second

b. Low: 0.30 degrees per second (maximum)

(3) Acceleration: 60 degrees per second squared

(e) Yaw control:

(1) Excursion: ± 28 degrees

(2) Velocity:

a. High: 60 degrees per second

b. Low: 0.15 degrees per second (maximum)

(3) Acceleration: 60 degrees per second squared

(f) Blanking: the FLOLS image shall extinguish when the aircraft is out of the normal viewing cone for a typical FLOLS. In the event that the simulated flight dynamics exceeds the FLOLS projector servo capability such as during a continuous aircraft roll, the image shall extinguish

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(g) Focus: as required to maintain optimum focus for all image positions on the screen

(h) Servo accuracy: servo accuracies shall be for all system servos as measured by the radial angle from the pilot's normal eye position between the center of the projected image to the proper location in three dimensional space, to either the carrier or airfield displayed images

(1) Static position accuracy: 6 arc minutes

(2) Dynamic tracking accuracy: 9 arc minutes

(3) Roll tracking accuracy: 1.0 degree for the angle between the projected datum bars and the landing field or deck geometric plane for worst case maneuvers

(i) Command rate capability: 60 per second with same computation rate as optical probe

(j) Light grouping control: all light groupings of the FLOLS shall be separately adjustable for maintenance and calibration purposes. The instructor shall have the capability to illuminate and extinguish the FLOLS lighting as well as separately initiating the cut-lights and wave-off lights (flashing at 90 flashes per minute)

(k) Light grouping dynamic position error:

(1) Datum lights: 6 arc minutes

(2) Cut lights: 15 arc minutes

(3) Waveoff lights: 15 arc minutes

NOTE: Angles specified is the error between the centroid of the Fresnel lenses and the centroid of the respective light groupings relative to pilot's normal eye position

(l) Light grouping brightness: 0 to 100 foot lamberts variable by computer control. Each light grouping shall be manually and independently adjustable.

3.7.8 <u>Target aircraft generation system</u> .- The target aircraft image shall be generated from a model viewed by a television camera. Proper target aircraft aspect along the line-of-sight shall be controlled by three axes of continuous rotation which orient the model. Target range shall be simulated by a combination of camera zoom lens and projector raster shrinkage. The zoom lens shall provide approximately

18:1 magnification and the raster shrinkage shall change approximately 5:1. The relative range of the target image shall vary from 400 to 36,000 feet. The target image shall present a correct perspective at 1,000 feet relative range.

3.7.8.1 Target aircraft model and drive mechanism.- Critical minimum, except as noted, level performance shall be as follows:

(a) Target model: (Specify type and model of adversary aircraft)

(b) Model reflectivity: 75 percent with diffuse finish

(c) Illumination: shadowless and uniform

(d) Instructor control: the target model shall be controlled in real time from the instructor station or preprogrammed and assigned as a tactics air target coordinated with radar, IFF, and communications systems

(e) Model servo drive performance (all servos with performance relative to adjacent field support structure)

(1) Excursion: continuous

(2) Velocity: 300 degrees per second

(3) Acceleration: 300 degrees per second squared

(4) Static accuracy: 0.2 percent

(5) Repeatability: 0.05 percent

(6) Dynamic range: 100 to 1

(7) Frequency response: the actual servo phase characteristics at any frequency shall match within 25 percent of an ideal 0.7 damped 25 radian per second, second-order system over a frequency band of 0 to 3 Hz

(8) Time response: the actual time response at any time shall match that of an ideal 0.7 damped 25 radian per second, second-order system within 25 percent of the step amplitude.

3.7.8.2 Target aircraft TV system.- The target model shall be viewed by a high resolution TV camera. The following subassemblies comprise the target TV system:

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3.7.8.2.1 Camera zoom lens.- The camera shall mount a zoom lens of at least 20:1 focal length range. This lens shall be driven simultaneously with the raster size variation to provide a total zoom range of at least 90:1. This lens shall be operated over the range of 12.8 - 230 mm to provide approximately 18:1 zoom range, and correct perspective at a simulated distance of 1000 ± 100 feet.

3.7.8.2.2 Camera zoom servo.- The camera zoom servo controls the motions of the optical elements within the camera zoom lens. The input to this servo is a position voltage command. The output of the zoom servo is the relative motion between the fixed lens housing and the rotating lens barrel. This servo shall be driven by an electric d.c. torque motor. The servo specifications listed below are a function of the magnification characteristics of the camera zoom lens and are based upon an Angenieux 20:1 zoom lens:

(a) Excursion:	200 degrees
(b) Velocity:	50 degrees per second
(c) Acceleration:	200 degrees per second squared
(d) Static accuracy:	0.1 percent
(e) Repeatability:	0.04 percent
(f) Dynamic range:	500:1
(g) Frequency response:	same as 3.7.8.1(e)(7)
(h) Time response:	same as 3.7.8.1(e)(8).

3.7.9 Formation and tanker aircraft generation system.- Aircraft images for formation flight and in-flight refueling simulation shall be generated from interchangeable models viewed by a gantry mounted television camera. Proper aircraft image aspect along the line-of-sight shall be controlled by three axes of rotation which orient the model. Target range shall be simulated by a combination of camera (gantry) motion, and projector raster shrinkage. (Details of the formation and tanker aircraft generation system depend upon the type(s) of aircraft to be simulated.)

3.7.10 Special effects generation system.- A special effects generator shall be provided to generate appropriate video for mixing with the target scene video. Special effects inclusion and parameter values shall be selectable at the instructor station.

3.7.10.1 Special effects performance.- Special effects shall include the following and shall meet the specified minimum performance levels:

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(a) Visibility: shall comply with 3.7.10.1.1

(b) Special scene effects: haze and fog

(c) Overcast ceiling range: variable in steps of 500 feet from 1,000 to 15,000 feet and continuously variable below 1,000 feet

(d) Undercast ceiling range: variable in steps of 500 feet from 1,000 to 15,000 feet and continuously variable below 1,000 feet

(e) Horizon accuracy: $\pm$ 0.5°.

3.7.10.1.1 Special effects (visibility).- The visibility range of the image shall be selectable by the instructor for a range of zero to 30 nautical miles by selection from a minimum of any ten discrete simulated ranges. The restricted visibility shall manifest itself in a "natural" fashion by superimposing on the scene video a flat gray tone signal whose intensity is proportional to the slant range of the scene video. Control shall be provided to the instructor which shall permit an adjustment of the tone of the visibility restricting signal continuously from full white to full black.

3.7.11 Target projection system.- The target projection system shall provide a 60 degree field of view for carrier and field takeoff and landing, air-to-ground weapons delivery, formation flight and in-flight refueling simulation. A 15 degree field of view shall be provided for air-to-air combat simulation. The target images shall be superimposed over the projected background scene derived from the background projector.

3.7.11.1 Target projection system performance.- The target projection system in conjunction with each target image generation system shall provide all target images on the display screen with the following minimum performance levels measured from the pilot's nominal eye position in the cockpit:

(a) Resolution:	14 minutes of arc per optical line pair (horizontal and vertical at center of 60 degree projection field)
	16 minutes of arc per optical line pair (horizontal and vertical at edges of 60 degree projection field)
	4 minutes of arc per optical line pair (horizontal and vertical at center of 15 degree projection field)

5 minutes of arc per optical line pair (horizontal and vertical at edge of 15 degree projection field)

(b) Image luminance: 2 foot-Lamberts (both lenses, background raster shall be extinguished except for ground targets)

(c) Gray scale: 8 shades of gray

(d) Geometric distortion: 2 percent (60 degree projection angle)

5 percent (15 degree projection angle)

(e) A Raster Control unit shall be provided. This unit shall provide simultaneous control of horizontal and vertical raster size on the projection CRT. Size shall be variable from 5.0 inches to less than 0.75 inches (horizontal and vertical) on the face of the CRT. A keystone correction circuit shall provide vertical keystone correction. Both raster size and keystone shall be controllable by external d.c. voltages

(f) CRT protection circuitry shall be incorporated. Application of high voltage shall be delayed from power turn on and gradually increased to full operating voltage. Sweep failure circuitry shall cut off beam current in the event of a sweep or power failure with sufficient speed to protect the projection tube from physical damage

(g) All power supplies shall be solid state and regulated to compensate for line variations from 105 to 125 vac.

3.7.11.1.1 Target image luminance.- The luminance of all target images on the spherical screen shall not be less than 1.5 foot-Lamberts as seen from any point within a viewing volume of 1 foot radius about the nominal pilot eye position with a goal of 3 foot-Lamberts. The luminance of all target images shall not change by more than 1 foot-Lambert when measured from any two points within the above viewing volume as the target image is moved throughout the cockpit field of view. The uniformity of target image luminance shall be such that the maximum contrast variation in a uniform field picked up by the probe from a uniform screen shall not exceed 30 percent. The spectral sensitivity of the measuring device for photometric data, shall not deviate by more than 10 percent from that of the (photopic) standard eye.

3.7.11.2 Projection optical system.- Refractive projection optics shall be used to project the final image onto the spherical display screen. The lens system shall project information displayed on the projection CRT faceplate. Two projection lenses shall be provided: a wide angle lens and a narrow angle lens. Folding mirrors shall be utilized to provide a compact projection assembly. The CRT shall be positioned by a focus servo to maintain focus as lens-to-screen distance varies. The minimum performance for the projection lenses shall be as follows:

3.7.11.2.1 Wide angle projection lens.- The minimum performance for the wide angle projection lens shall be as follows:

(a) Focal Length	5-inches maximum
(b) F-number	f/1.3 maximum
(c) Clear Aperture	As determined by FL and f/number
(d) Lens-to-screen Distance	125 inches nominal
(e) Lens full angle	60 degrees
(f) Axial Transmission	75 percent
(g) Resolution	20 line pairs per millimeter on axis
(h) Relative Illumination	50 percent at half field
(i) Image (CRT) Format	5 inch diameter covering circle.

3.7.11.2.2 Narrow angle projection lens.- The minimum performance for the narrow angle projection lens shall be as follows:

(a) Focal length	18 inches
(b) F-number	As required to achieve performance of 3.7.11.1 of this specification
(c) Clear aperture	5 inches
(d) Lens to screen distance	As required to achieve performance of 3.7.11.1 of this specification
(e) Lens full angle	15 degrees
(f) Axial transmission	75 percent

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(g) Resolution — 40 line pairs per millimeter

(h) Relative illumination — 50 percent at 0.8 field

(i) Image (CRT) format — 5 inches dia covering circle.

3.7.11.2.3 Optical system transmission.- Total light loss through the optical system (projection lens, field flattener lens and projection mirrors) shall not exceed 30 percent.

3.7.11.3 Projection CRT (Focus) Servo.- The projection CRT servo drive shall control the motion of the CRT within the projector. The input to the servo shall be a position command. The output of the projection CRT servo shall be the relative motion between the fixed lens and the moving CRT carriage. This servo shall be driven by an electric d-c torque motor. The minimum performance of the CRT (focus) servo shall be as follows:

(a) Displacement (nominal)	2.5 inches
(b) Velocity	12 inches per second
(c) Static accuracy	0.8 percent
(d) Repeatability	0.2 percent
(e) Dynamic range	100 to 1
(f) Frequency response	The focus servo shall provide a position error during steady-state tracking which is less than 0.02 second for any velocity within the specified dynamic range
(g) Time response	The actual servo time response at any time shall match that of an ideal 0.7 damped 25 radian per second, second order system to within 10 percent of the step amplitude.

3.7.11.4 Azimuth and elevation servos.- The azimuth and elevation servos control the angular motions of the projector assembly. The output of the elevation servo is the relative rotation about the elevation axis between the main support of the elevation gimbal and the adjacent supporting structure of the azimuth gimbal. The output of the azimuth servo is the relative angular motion about the azimuth axis between the main support shaft of the azimuth gimbal and the fixed adjacent support structure. Servos shall be driven by electric d.c. torque

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motors. The minimum performance for the azimuth and elevation servos shall be as follows:

(a) Displacement (nominal)	$\pm$ 90 degrees (elevation) continuous (azimuth)
(b) Velocity	300 degrees per second (both servos)
(c) Acceleration	800 degrees per second squared (both servos)
(d) Static accuracy	0.08 percent (both servos)
(e) Repeatability	0.02 percent (both servos)
(f) Dynamic range	1000 to 1
(g) Frequency response	The actual servo characteristics at any frequency shall match within 10 percent that of an ideal 0.7 damped 25 radian per second, second-order system over a frequency band of 0 to 3 Hz
(h) Time response	The actual servo time response at any time shall match that of an ideal 0.7 damped 25 radian per second, second-order system to within 10 percent of the step amplitude.

3.7.12 Sky-earth projection system.- A sky-earth projection system shall be provided to project an earth, sky and mountainous horizon onto the display screen. The system shall consist of separate projectors, a sky-horizon projector and an earth projector. The sky-horizon projector and the earth projector shall be point light source projectors having partial spherical projection transparencies. The projectors shall be mounted on a single multiple-axis gimbal system that allows the background scene to be rotated by servo drives controlled by computer signals. The sky projector shall consist of a tinted blue transparent spherical section around a point light source. The earth projector shall consist of a tinted brown transparent spherical section around a second point light source. The point light motions relative to the spherical transparencies shall be controlled and synchronized as a function of the motions of the sky-earth gimbal mechanism in a manner such that projection distortions due to changing gimbal positions are avoided in the mapping of the sky-earth scene on the spherical screen.

3.7.12.1 <u>Sky-earth projection system performance</u>.- The sky-earth projection system shall provide a background scene with the following minimum performance levels measured from the pilot's nominal eye position in the cockpit:

(a) Resolution:	15 minutes of arc per optical line pair
(b) Field of view:	240 degrees
(c) Image luminance:	0.5 foot-Lamberts (with a design goal of 1.0 foot-Lamberts)
(d) Color:	Blue sky, brown earth, black mountains
(e) Geometric distortion:	1 percent.

3.7.12.2 <u>Sky-earth gimbal servos</u>.- The sky-earth gimbal servos shall operate in conjunction with the point light source positioning servos to project the earth, sky and horizon to the correct position on the display screen relative to the pilot's nominal eye position for all possible aircraft simulated attitudes. The minimum performance of all the sky-earth servos shall be as follows:

(a) Displacement:	Continuous
(b) Velocity:	300 degrees per second
(c) Acceleration:	800 degrees per second squared
(d) Static accuracy:	0.25 percent
(e) Repeatability:	0.03 percent
(f) Dynamic range:	500 to 1
(g) Frequency response:	The actual servo phase characteristics at any frequency shall match within 10 percent of an ideal 0.7 damped 25 radian per second, second-order system over a frequency band of 0 to 3 Hz
(h) Time response:	The actual servo time response at any time shall match that of an ideal 0.7 damped 25 radian per second, second-order system within 10 percent of the step amplitude.

3.7.12.3 Point light motion servos.- Spatial positioning point light servos shall operate in conjunction with the sky-earth gimbal servos to project the earth, sky and horizon to the correct position on the display screen relative to the pilot's nominal eye position for all possible aircraft simulated attitudes. The minimum performance of all the point light motion servos shall be as follows:

(a) Displacement (nominal):	7 inches
(b) Velocity:	30 inches per second
(c) Acceleration:	1000 inches per second squared
(d) Static accuracy:	0.15 percent
(e) Repeatability:	0.03 percent
(f) Dynamic range:	500 to 1
(g) Frequency response:	The actual servo phase characteristics at any frequency shall match within 10 percent of an ideal C.7 damped 25 radian per second, second-order system over a frequency band of 0 to 3 Hz
(h) Time response:	The actual servo time response at any time shall match that of an ideal 0.7 damped 25 radian per second, second-order system within 10 percent of the step amplitude.

3.7.13 Visual system controls.- Controls for the operation and maintenance of the visual system shall be provided. Operating controls required by the instructor during the training and checkride mode of operation shall be located at the instructor station. Maintenance controls shall be appropriately located for their intended use and shall include those indicators below as well as any others which may be required. A visual display scene monitor shall be located appropriately for use in conjunction with these controls. Provision shall be made so that any and all necessary on-line adjustments to the visual display viewed by the pilot can take place without interruption of training and checkride mode activities:

(a) ON/OFF as may be required for each major subassembly (e.g., cameras, gantries, model illumination, point light sources)

(b) Gantry/probe positioning and slewing

(c) Model lighting

(d) Special effects generator controls

(e) Probe focus adjustment

(f) Television camera controls

(g) Controls associated with the display monitor located in the maintenance area

(h) Controls associated with the FLOLS optical projector system

(i) Controls associated with all target image generation systems.

3.7.14 Instructor station.- The visual system shall be controlled from the existing instructor's console. The instructor station shall contain all controls and indicators necessary to operate the visual system and to control, monitor, and record the subject's performance. The instructor station shall contain a television monitor to display the view of the target image that is presented to the pilot. Also, the instructor station shall contain a display of the FLOLS image that is presented to the pilot. The FLOLS and target images may be provided on separate display devices. The instructor station shall include the following controls:

(a) Visual system operation and maintenance controls and indicators

(b) Initialization controls to set the initial positions of the aircraft and aircraft carrier

(c) Carrier and target aircraft motion control including simulated carrier speed, heading and the sea state

(d) On-off switch to control missed hook or bolter simulation

(e) Freeze control

(f) FLOLS control including activation, relative brightness, glide slope landing signal angle, wave-off light signal, and independent control of "meatball" and data lights

(g) Carrier deck lighting including activation and intensity.

3.7.15 Digital computation system.- A digital computer system shall be provided to drive the visual system. The computer system shall consist of the computer, its interface with the trainer and peripheral equipment, and all software required to operate as a complete integrated system. The existing trainer program shall be modified and/or upgraded to provide aerodynamic and control information required by the visual system. The digital computer system shall provide simultaneous computation for and control of the instructor/operator station, visual system and other equipment as required with a minimum of conversion or transfer devices. The digital computer system shall be programed to perform the functions specified herein. The digital computer system shall comply with all functional, operational, simulation and design requirements of this specification. For purposes of this specification, the digital computer system shall include all trainer and control computers, visual processors, memory units, input/output (I/O) units, peripheral devices, mass storage devices, special interface equipment, all integral power supplies and all associated software programs. Because of economical and logistical considerations, as a goal the computer should be directly compatible with existing trainer computer hardware and software.

3.7.15.1 Multi-computer operations.- The visual computer shall be capable of communicating directly with its input/output equipment without involving the trainer computer. Provisions shall be incorporated for synchronization of the communications between the visual and trainer computers, and for controlling the computers with common operating controls such as start, halt, and system freeze. This can be implemented by either software or hardware.

3.7.15.1.1 Trainer spare time.- Existing spare time, up to a maximum of 2 milliseconds of the trainer computer program iteration cycle may be used to support the requirements of the visual system and to comply with 3.7.15.3.1 through 3.7.15.3.5 of this specification. (Existing flight simulators normally will have sufficient spare time in its program iteration cycle to support the visual system.)

3.7.15.1.2 Visual replay requirement.- Aircraft and motion platform position and attitude data shall be continuously stored on disc memory up to the capacity of unused disc storage or up to a maximum of 5 minutes. Provisions shall be made to replay the previous one minute operation or the previous five minutes of operation upon selection and initiation by the operator. Upon operator initiation, the visual digital computer system and the associated trainer computer system shall enter a freeze mode and cause a replay of the aircraft trainer's operation which will be shown on the pilot's display and operator's monitor. (Most existing simulator systems do not have disc storage, therefore in such cases the visual system would have to include sufficient disc storage to accomplish this requirement, if there is a requirement for replay.)

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3.7.15.2 Computer program deficiencies.- Deficiencies in the simulation program, discovered during the course of the contract made manifest by the addition of the visual system, shall be identified and defined by the contractor. The contractor shall recommend corrective measures for the computer program deficiencies in the Test Procedures and Results Report.

3.7.15.3 Computer simulation requirements.- The visual or simulator computer system shall be programmed in accordance with the simulation requirements of 3.2.7 and 3.7.15.3.1 through 3.7.15.3.5 and 3.7.15.4 of this specification.

3.7.15.3.1 Aircraft position and altitude calculations.- Altitude and x,y coordinate position of the simulated aircraft shall be calculated at a rate of 30 Hz. Predictive or extrapolation techniques shall be used to derive position and altitude information from the basic iteration rate of the simulator program at the 30 Hz rate required by the visual system.

3.7.15.3.2 Moving target simulation.- Programs shall be provided which will simulate the moving targets specified herein in accordance with 3.2.7.1 of this specification. Carrier speed, heading, and the sea state shall be selectable by operator action. Carrier position shall be calculated at the rate of 20 Hz minimum.

3.7.15.3.3 Arrested landing simulation.- Program(s) shall be written to simulate hook capture landings and bolters on a carrier. Dimensions used for FLOLS position, wire spacing, landing zone and related carrier landing system components used in the simulation of carrier landings shall be in accordance with actual positions and spacing on a FORRESTAL class aircraft carrier. Simulation of deceleration after hook capture shall be provided as appropriate to the simulated aircraft and FORRESTAL carrier capture system. Hook capture simulation shall result in outputs to the visual system to depict the visual cues associated with actual hook capture. Missed hook or bolters shall be simulated. Inhibitable print out of hook capture and zone, including wire numbers, in which capture occurred shall be provided. Outputs to the simulator motion system to cause appropriate motion cues associated with an arrested landing shall be provided.

3.7.15.3.4 Crash conditions.- Crash conditions presently sensed by the simulator program shall be output to the instructor. Flight and visual simulation shall go into a freeze mode when a crash condition occurs. Identifying information as to cause of crash condition shall be provided. In addition, the following crash conditions shall be sensed and outputs provided:

(a) Landing on the carrier outside the area in which successful landings or bolters can be made

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(b) Ramp strikes

(c) Crashes into water, runway, or other aircraft.

3.7.15.3.5 Catapult launch simulation.- Simulation of catapult launch from a carrier deck shall be provided. Simulation of acceleration on launch shall be provided as appropriate to the simulated aircraft and carrier launch system. Motion, aircraft control, visual cues and flight instrument indications associated with launch operations shall be simulated.

3.7.15.4 Initialization.- Provisions shall be made for the operator to initialize the position of the aircraft carrier and the position of the aircraft at the catapult launch position on the aircraft carrier. Also, provisions shall be made to initialize the position of the aircraft, by operator action, at the beginning position of the final approach to landing.

3.7.15.5 Visual system delay.- The maximum delay and lag through the visual system, measured from the time that given attitude and position information is presented from the simulator to the visual system to the time that the visual response to this given attitude and position information is displayed on the pilots display screen, shall not be greater than 50 milliseconds.

3.7.15.6 Visual computer requirements.- The visual computer requirements are the following:

3.7.15.6.1 Physical and environmental characteristics.- The visual digital computer, peripheral units and ancillary interface equipment shall meet the following climatic conditions:

(a) Temperature: from -20° to +130° Fahrenheit, operating, non-operating, and storage

(b) Relative humidity: up to 90 percent condensation

(c) Barometric Pressure: From 31.35 to 24.9 inches of Mercury

(d) No permanent damage shall be incurred as a result of failure of the trainer environmental control equipment

(e) Adequate internal ventilation, as well as abnormal temperature and airflow sensors and indicators, shall be provided and installed.

3.7.15.6.2 System growth capabilities.- The visual computer system shall be designed to permit expansion of computation capacity as specified below without significant design changes or modification to existing hardwar :

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(a) Memory - twenty-five percent of the total directly accessible high speed memory in modules no greater than 8192 words by the addition of memory modules to existing processor

(b) Input/Output - Fifteen percent increase in the total input/output channel capacity associated with the visual computation system

(c) Computation speed - Thirty-three percent increase in the system's average computation speed. The use of additional identical central processing units or high speed arithmetic options are acceptable for meeting this requirement.

3.7.15.6.3 Visual computer selection.- Only a commercially available general purpose digital computer, and peripheral units that are currently in production and in general use by other than the computer manufacturer shall be selected and employed to satisfy the requirements of this specification. Procurement specifications and standards for the visual computer are the responsibility of the contractor. They shall include all requirements as stated herein. All hardware and software shall be provided as specified herein. Other considerations to be applied in the selection and design of the digital computer system shall be initial and life cycle costs, future availability, reliability, flexibility, versatility, ease of programing, maintainability, and its adaptability to the incorporation of system performance changes.

3.7.15.6.4 Computations for visual display system.- The visual computer shall provide memory, speed, iteration rate, word length, and I/O interface and conversion equipment to meet the requirements of the visual system. Visual system control inputs and data outputs shall be connected to the visual computer by means of a computer interface which will provide the necessary digital-to-analog (D/A) and analog-to-digital (A/D) channels, digital outputs and inputs, and synchro outputs required to integrate with the visual system and with the simulator system.

3.7.15.6.5 Computer configuration requirements.- The visual computer may interface and utilize existing spare trainer computer memory subject to the requirements of 3.7.15.6.9(c) of this specification. Word length, processing capacity and speed, and I/O capacity and speed necessary to meet the total requirements of this specification shall be provided.

3.7.15.6.6 Instruction repertoire.- The instruction repertoire of the visual computer shall include, as a minimum, instructions to provide:

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(a) General arithmetic processing capability

(b) Address modification, tallying and programed loop control by indexing

(c) Signed multiply and signed divide capability by hardware algorithms

(d) Conditional and unconditional branching and transfer of control

(e) Logical processing - such as shifting, normalizing, Boolean functions, connectives and the like

(f) Data transmission instructions (involving storage) such as: load and store

(g) Complete set of I/O instructions for controlling the interfaces and the peripheral devices

(h) Special register instructions such as set, clear, complement, index register control, bit testing and the like.

3.7.15.6.7 Computer I/O capability.- The I/O system of the visual computer shall provide the following capabilities:

(a) Capability to service assigned blocks of data to and from the I/O channels and high speed magnetic core memory without restricting the operation of the arithmetic unit except for any initial set-up and memory access priority delays. (e.g., a direct memory access (DMA) capability through the medium of memory port(s) in conjunction with an I/O processor)

(b) Capability to communicate directly with all interface equipment

(c) Capability to input or output to and from one or more units of peripheral equipment while continuing operation in the real-time simulation and processing modes

(d) Capability to provide, under program control, interrupt lines by which the computer can be interrupted by external discrete controls, devices and/or another computer

(e) An error checking feature to check I/O transfers is desirable.

3.7.15.6.8 I/O system standardization.- Standardization of form and format of I/O data quantities shall be established for the computer side

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and the interface side such that, to the greatest extent possible, identical parameters performing identical functions in different trainer areas shall be based on the same computation and processing and have the same resolution and accuracy. All inputs and outputs from and to the visual system shall be at a rate of no less than 30 times per second unless excepted by other sections of this specification.

3.7.15.6.9 Memory requirements.- The visual computer shall utilize high speed random access magnetic core memory to store the total system simulation, control programs, and executive programs and all constants, real-time data operands and intermediate results. Spare core memory in the simulator computer may be used subject to the requirements of 3.7.15.6.9(c) of this specification. If spare core memory in the existing simulator computer is insufficient to support the requirements of the visual system, then the contractor shall provide the core memory required. The memory requirements include the following:

(a) Memory cycle time requirements: The high speed magnetic core memory cycle time shall be based on transferring full length computer words. Overlapping of memory modules (banks) shall not be utilized as a technique to decrease memory cycle time

(b) Disc (mass) storage requirements: Mass storage is required for the system in the form of a magnetic disc and controller. All real-time simulation programs, all maintenance, test and diagnostic programs, all utility and related programs shall be stored on the disc(s). Existing simulator computer disc systems may be used subject to the requirements of 3.7.15.6.9(c) of this specification. The use of real-time overlaying techniques from mass store (discs) shall be limited to data only. It shall not be used for reducing resident real-time program storage requirements for high speed magnetic core memory

(c) Spare memory and storage requirements: Not more than 75 percent of high speed magnetic core memory and 75 percent of mass storage (disc) shall be utilized in meeting the total program and data storage requirements of this specification. These percentages apply to existing spare core and disc memory. It shall be provided in blocks of contiguous locations not less than 100 words in length and shall apply to the computer utilized in the system. All core and disc memory provided and used shall each satisfy the following expression:

$$MEM_{used} + MEM_{spare} \leq MEM_{installed}$$

where

$$MEM_{spare} \geq .25\ MEM_{installed}.$$

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3.7.15.6.10 Visual computer control panel.- A visual computer control panel shall be provided with the visual computer. The panel may be located on a separate console or may be incorporated into a centralized panel located on the main rack or cabinet of the computer. Switches, indicators, and controls necessary for operation of the computer shall be located on the control panel. The panel shall incorporate provisions for manual insertion of instructions and data and shall contain display indicators to enable operating and maintenance personnel to monitor the operation of the computer. The operator shall have the ability to control the computer from a seated position with provision for a work top area.

3.7.15.6.10.1 Register information display and insertion.- Display indicators shall be provided to permit selection and visual examination of the content of any memory address and any binary stage of program accessible registers. Hardware switches and associated controls shall be provided to permit insertion of information in any memory address and in any binary stage of program-accessible registers.

3.7.15.6.10.2 Halting provisions.- Means shall be provided to halt the computer at any preselected program step. A switchable (ON/BYPASS) halt-on-parity error provision is desirable. With this provision, parity error indicator lamps shall be provided on the control panel.

3.7.15.6.10.3 Single-step provisions.- Single instruction advance is required and single clock pulse advance is desirable for stepping the program in the visual computer.

3.7.15.6.10.4 Power fail-safe provisions.- A power fail-safe interrupt provision shall be included with the computer to sense impending power failures and permit storage of volatile registers and accomplish memory lock-up. Power failure or emergency interruptions of power to the trainer and/or computer shall not result in physical or electrical damage to the computer system equipments.

3.7.15.6.10.5 Real-time clock.- A program addressable real-time clock integral to the computer shall be provided with program control of the generation of necessary interrupt timing intervals.

3.7.15.6.10.6 Visual computer speed requirements.- The visual computer shall have sufficient arithmetic, logical processing and memory access speeds to assure real-time processing of all displays, simulation, visual and control programs with no discrete stepping, oscillating or erratic display indication and to provide a mathematically consistent and stable solution of the system equations. Required minimum solution rate or iteration rate for each visual computation program module grouping shall be 30 per second.

3.7.15.6.10.7 System spare capacity.- The visual digital computer system as installed and accepted shall provide the following spare capacity without necessitating any additional hardware modifications:

(a) The total processing time utilized in the worst case logical path during any program iteration or solution cycle shall not exceed 75 percent of the time available for that iteration or solution cycle. The following expressions shall apply:

(1) $T_A + .25\ T_B \leq T_B$

and

(2) T_C + 250 millisec persec   1000 millisec persec or

T_C 750 millisec persec

T_A = Total time worst-case processing per shortest iteration cycle

T_B = 30 milliseconds

T_C = Time total processing worst case per second

All times are expressed in milliseconds.

(b) Fifteen percent of the I/O channel capacity of the visual computer shall be spare. Channel capacity refers to both the number of lines and the number of devices that can be controlled by a single channel as well as the data transfer capacity (rate) of the computer in full length words

(c) Fifteen percent of the interface channel capacity shall be spare. The spare interface channels shall include all analog-to-digital, digital-to-analog and digital-to-synchro conversion capacity and shall be distributed such that 15 percent spare for each type of channel and channel speed shall exist for each separate interface.

The visual digital computer system shall have the spare memory capacity, spare I/O capacity, and spare processing capacity (time and speed) as specified above and in 3.7.15.6.9(c) of this specification.

3.7.15.6.10.8 Peripheral equipment.- The visual computer peripheral equipment shall be provided to support the digital computer in meeting the requirements of this specification. The following peripheral devices are the minimum required. (The following peripherals are recommended but depend mainly upon the specific system requirements of the simulator system to which the visual system is attached.)

(a) An ASR-35 alphanumeric keyboard/printer teletypewriter device shall be furnished and installed with each computer of the system. Tape format and form shall be compatible with (b) and (c) below

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(b) A high speed punched tape reader (with automatic take-up reel) which is capable of reading 8-level punched tape (oiled or unoiled) including a parity bit at a speed of at least 300 characters per second. Use of fan-fold tape and holders will not be acceptable in meeting this requirement

(c) A high speed tape punch which is capable of punching 8-level paper and aluminum-backed mylar tape in a format including a parity bit compatible with the punched tape input devices. Minimum punching speed shall be 110 characters per second

(d) A high speed alphanumeric line printer, with controller, shall be provided and installed. This device shall be capable of printing a minimum of 130 USASCII coded alphanumeric characters per line of print at a rate of not less than 300 lines per minute. Printing format shall be under program control using USASCII control characters (e.g., space, tab, line feed and the like). The printer shall be capable of accepting and using standard edge-perforated fan-fold paper having a minimum width of 15 inches to include multiple carbon copy types.

3.7.15.6.10.9 Standard coding for character sets.- All computer I/O peripheral equipment and character (byte) oriented interface equipment logic (including diplay alphanumeric keyboards) shall be hardware compatible with the USASCII (United States of America Standard Code for Information Interchange) standard for coded alphanumeric character sets as specified in MIL-STD-188.

3.7.15.6.10.10 Interface equipment.- The visual system and digital computer system interface equipment shall include all input/output conversion equipment and discrete inputs and outputs. The interface shall be designed to permit sampling of controls and activation of displays and the like with sufficient speed and accuracy to meet the requirements of this specification and to minimize I/O errors. The interface equipment design shall be based on concepts, logic techniques and circuit modules utilized in the computer to the greatest extent practicable. A minimum number of different circuit types (and modules), cards and the like, consistent with design requirements shall be utilized.

3.7.15.6.10.11 Interface power operation.- The visual digital computer shall be capable of normal operation with utility programs, memory test programs and CPU test programs independent of interface power. (i.e., with interface power turned off, the computer shall run normally.)

3.7.15.6.11 Digital computer maintenance provisions.- The following provisions shall be made for maintaining the digital computer:

3.7.15.6.11.1 Accessibility.- The selected visual digital computer shall have a design which permits free access for trouble-shooting and normal servicing. Extender cards shall be provided for each separate type of mechanical card connector utilized.

3.7.15.6.11.2 Running time meter.- A running time meter shall be installed in the visual computer and shall indicate the elapsed computer "on" time. The meter shall display at least five digits in increments of 0.1 hour.

3.7.15.6.11.3 Maintenance and test programs.- Maintenance programs shall test the operation of both the computer and the visual simulator equipment. When a malfunction occurs in the computer or visual simulator equipment, these programs shall provide sufficient information to the operator to facilitate location and correction of the malfunction in accordance with the MTTR requirements of this specification. They shall be capable of running with a minimum of operator intervention. The maintenance and test programs shall be:

(a) System daily readiness check programs

(b) Computer diagnostic programs (commercially available)

(c) System (device) test and calibration programs.

3.7.15.6.11.4 System daily readiness check programs.- A daily readiness check program(s) shall be provided to enable operating personnel to determine visually that the visual system is ready for operation. The program(s) shall require less than 30 minutes (15 minutes desired) execution time.

3.7.15.6.11.5 Real-time interface equipment diagnostic program.- Program(s) shall be provided which will enable on-line program diagnosis of the visual/simulator interface equipment and visual computer/visual system malfunctions. These program(s) shall be automatic and require a minimum of operator effort. They shall provide a hard-copy print-out of the nature of the malfunction and of the test(s) results.

3.7.15.6.11.6 Discrete input and output check-out program.- The program shall provide for checking the proper functioning of the discrete input and output channels of the visual system in a closed loop manner. All disconnection and reconnection shall be accomplished under program control or by a patchboard-type device. The operator shall also visually verify the correct status of discrete indicators and determine the proper operation of manual switches which interact with this test program. The program upon detecting a malfunction shall indicate the failing channel to the operator via on-line hardcopy print-out.

3.7.15.6.11.7 Analog input and outputs check-out program.- Programs shall be provided to test all analog channels and devices through their

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full range of operation. This shall be accomplished in a closed-loop fashion using a known accurate and calibrated digital-to-analog converter as a reference. All disconnection and reconnection shall be accomplished under program control or by a patchboard-type device. The tests shall be designed and programed so that accuracy limits can be specified by operator inputs. All channels not functioning within design limits shall be indicated to the operator via hardcopy print-out. A dynamic test of the analog output channels shall also be provided. These tests shall enable the operator to specify a variation of period and amplitude of the test signals to a specified channel.

3.7.15.6.11.8 Computer diagnostic programs.- Only commercially available diagnostic programs for the selected computer shall be used. Inadequacies of the proposed commercial programs in meeting this specification shall be documented. All diagnostic programs shall be fully automatic to the extent that once the operator has loaded the program and set up initial conditions, he need only observe automatically-generated error indications. Emphasis shall be placed upon the detail with which the diagnostic program describes and defines the errors encountered and the automation of program execution.

3.7.15.6.11.9 Computer arithmetic unit, control unit and I/O unit diagnostic programs.- Tests performed by these commercially available programs shall check the operation of each machine instruction (i.e., add, load, store, etc.) and the functioning of the complete arithmetic unit, control unit and I/O unit of the computer. The tests shall have the option of cycling on a single instruction or executing the complete repertoire. Upon encountering a malfunction, the program shall indicate to the operator the type and nature of the failure via on-line hardcopy device, or, where necessary, program halts at an address which can be related to the malfunction by reference to a diagnostic manual.

3.7.15.6.11.10 Memory test program.- Standard commercially available memory test program(s) for the selected computer shall be used if special built-in memory test hardware is not integral to the memory modules. It is desirable that: (1) the memory test program(s) indicate errors to the operator (where feasible due to the nature of the error) via print-out; (2) the program have an operator controlled option of recycling on a single memory location for indication of detected errors to the operator via print-out; (3) all memory units (or modules) be tested (be either integral hardware or by the memory test program) in the following manner:

(a) Write and read all zeros in all addresses

(b) Write and read all ones in all addresses

(c) Write and read special test words entered from the computer control panel of designated addresses

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(d) Write and read the worst-case pattern for the particular type of memory being used (e.g., for a coincident current core memory a worst-case double-offset checkerboard pattern) in all addresses

(e) Worst-case cross-talk accessing for all addresses.

3.7.15.6.12 System software design requirements.- The design procedures of all system simulation and control programs shall include (1) preparation and compilation of complete and detailed flow diagrams, (2) source language coding, (3) program assembly and debugging, and (4) verification. The programs are required to implement all functional requirements of this specification. Symbols used in flow diagrams shall be in accordance with ANSI X3.5 Flowchart Symbols for Information Processing.

3.7.15.6.12.1 Program language requirements.- A master copy in both source language and object language of all software programs associated with and required by the visual device shall be prepared, checked out, and documented in a form and format acceptable to the computer I/O peripheral equipment specified in 3.7.15.6.10.8 of this specification. Programs shall be directly compatible with the computer. The programs shall include:

(a) The main visual program consisting of all real-time simulation, control, processing, executive and other required routines

(b) System utility programs consisting of, but not limited to, assembler, loader, conversion, memory dump, print-out, and real-time monitor (or operating system) routines. Commercially available utility programs shall be used when available for the selected computer.

3.7.15.6.12.2 Real-time simulation, control and processing program.- Real-time programs shall be designed to perform all simulation, control and processing (e.g., display processing and visual computations) required for the feasibility model. The visual computer shall be programed to accurately simulate the static and dynamic characteristics of all the visual systems. The following criteria shall be employed in the design and development of the programs in the order specified below:

(a) All real-time simulation, control and processing programs shall be designed, flow-charted, partitioned, and logically organized as a set of modular routines which shall be independently coded from the detailed flow-charts. Each modular routine (and subroutine) shall be coded to occupy contiguous memory locations. Utility type routines (and functions) (e.g., utility math routines, numerical constants and the like) shall be coded, stored and utilized

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as common references by all program modules as necessary. Cross-references for coding symbology shall be established and rigidly controlled to facilitate comparison between the detail flow diagrams and program listings. Changes to contractor internally approved (released) flow diagrams shall be controlled and documented in a manner similar to a formal released drawing DCN (Drawing Change Notice) system

(b) Instructions in each overall program shall not be altered by real-time program execution during the course of the training exercise

(c) The programs shall be designed and organized to include provisions for insertion of problem parameters under control of the executive routine via the specified computer input equipment and from other equipment such as instructor consoles and keyboards. The possible inputs shall include, but not be limited to, initial problem conditions, problem variables, trainee performance tolerances and recording requirements, simulated system malfunctions, system freeze conditions and the like

(d) To preclude crash of the camera probe into the model, the computer shall be programmed for minimum altitudes and maximum sink rates over level regions of the model and for minimum horizontal approach distances and maximum closure rates to vertically elevated regions of the model.

3.7.15.6.12.3 Initial problem conditions.- The existing simulation program shall be modified to contain initial condition parameters for the simulated aircraft. Not fewer than two preselected sets of initial conditions shall be provided and shall include attitude, altitude, velocity, heading, geographical location, and appropriate flight, engine and navigation instrument readings. The contents of the sets and its mechanization shall be subject to approval by the Procuring Contracting Officer. The sets shall be stored and addressable under executive routine control from the instructor station to permit changing of values or to verify existing content.

3.7.15.6.12.4 Initial problem condition modifications.- Initial condition data shall be addressable from the instructor console(s) via keyboard under control of the executive to permit changing of values or to verify existing content. When initiated by the instructor, a hardcopy print-out of initial condition data or display of initial condition data on a selected display shall be made for verification of proper entry or to permit the changing of the initial data.

3.7.15.6.12.5 Problem freeze and restart provision.- It shall be possible for the instructor to freeze the total simulation problem at any time, or at a preselected (via program) time or condition. The routine for freeze control shall permit displays, etc. and other computer controlled outputs to retain all indications and system status conditions that existed at the time of freeze initiation. Deactivation of the freeze shall restore the system to the conditions that existed at the time of the freeze and permit a resumption of the simulation mission.

3.7.15.6.12.6 Zeroing mode provisions.- A zeroing mode (subroutine) shall be included which, when activated by the instructor, shall return the simulation problem to the initial conditions selected by the operator.

3.7.15.6.12.7 Program cycle and problem solution rates.- The visual system program(s) shall be designed and organized to execute the total program at cycle and solution rates to avoid computational instabilities, to insure real-time dynamic response, and to eliminate perceivable delays between inputs and visual responses. The program may be organized to provide for subcycle processing rates for selected portions as required, providing the requirements of 3.7.15.6.10.6 and 3.7.15.6.10.7 of this specification are not compromised or modified.

3.7.15.6.12.8 Off-line function generation data program.- For dynamic vehicle simulation, vehicle function data may be incorporated into the main program(s). In the event stored function data are derived by an off-line computer program, this program shall be included in the program package. The program, running procedures and complete description shall be included in the programing manual documentation requirements as listed in the contract schedule.

3.7.15.6.12.9 Utility programs.- Existing commercial utility programs, including assembly programs, loading programs, data conversion programs, diagnostic programs, print-out programs and the like, shall be directly compatible with the visual computer.

3.7.15.6.12.10 Detail program design requirements.- In the design of all visual system programs, the following requirements shall be met. Basic design data accumulated for each program module shall include a narrative description and a detail flow diagram portion as well as the following:

(a) A functional block diagram indicating the major components of the total program, their interrelationships, and their interfaces with the I/O program

(b) For all program modules (routines), a listing of the functions performed, the necessary equations, definitions and scalings of all terms, and decimal and binary values or ranges of constants and variables used in the equations

(c) A listing and derivation of all equations and algorithms required to describe each program module

(d) Listing of subroutines, where used. These shall be described at the same level as a program. The listing shall include comments and especially scaling factors in both decimal and binary form

(e) Listing of all tables used, whether by lookup routine, or an interpolation routine. The listing shall include comments with decimal value, binary value, scale factors, and a cross-reference to the equations and program elements using them

(f) Memory allocation data, showing the absolute location of program modules in the visual computer memory (including allocation and location of routines on the disc which is part of the system)

(g) Listings of each problem variable with abbreviations showing all program modules or equations using that variable for reference in future modification

(h) Cross-reference indicators to facilitate using the overall flow chart together with the detail module flow charts and the equation/algorithm listings

(i) Listings of all variables using the standard aerodynamic symbology and terminology

(j) Listing of all data stored in memory with the following descriptions for each data word:

(1) Organization of table or tables, absolute memory location and dimension of tables

(2) Reference equations where used

(3) Number of bits

(4) Data formats

(5) Scaling factor (in decimal and binary form).

3.7.15.6.12.11 System program verification.- Programs shall be designed and coded to verify the simulation and display processing programs during the design and development effort. These programs shall provide a means of checking and verifying the overall correctness of the main simulator, control and other processing programs independent of the subject station and the computer interface equipment. The verification program shall provide a means of confirming that the visual system accurately follows and depicts the correct scene in response to inputs. This program shall accept pseudo inputs representing simulator

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simulation program operating on these pseudo inputs. The pseudo inputs accepted by the verification program shall be generated previously, based on selected test cases established from the system requirements. The operational program shall be run in conjunction with the verification program on the visual computer. Final debugging shall be done on the visual computer. The processing of the operational program in conjunction with the verification program shall permit the use of the general purpose features (e.g., dumps, print-outs) of the digital computer to provide information required for verification without the difficulties entailed in the special purpose data formats and the system inputs and outputs. The following procedureal sequences are normally used in performing the verification:

(a) Generation and selection of test case data for verification of the logical and computational flow of the simulation program

(b) Nonoperational trace of the logical sequence of the simulation program utilizing logic test-case data and the verification program

(c) Operational trace of the simulation program computation utilizing prepared test-case data and the verification program

(d) Comparison of the results of the trace program with precalculated solutions using the test-case data to determine if errors are present.

3.7.15.6.12.12 Program debugging and verification procedures.- Program debugging techniques, which necessitate single-step, operator controlled program operation, shall be kept to a minimum. Verification of the visual simulation programs shall be independent of the simulation equipment. This shall be achieved by processing it through the verification program, utilizing the visual computer. Test cases which fully test the visual simulation program shall be divided into logical units for use in debugging procedures and isolation of error sources.

3.7.15.6.12.13 Cycle time measurement program.- The contractor shall design and code programs which will determine the time actually required to execute the operational programs. Measurements provided by the program shall include the following items of data:

(a) The average execution times of each of the real-time program modules (accumulated over a 20 minute period)

(b) The worst-case execution time of all program module(s) that is logically and realistically possible for the shortest solution or cycle time (accumulated over a 20 minute period) (to prove execution time meets the requirements of paragraph 3.7.15.6.10.7(a) of this specification)

(c) Total execution time of each program part run at the assigned cycle rates.

3.7.16 Math model.- A mathematical model shall be derived for the control and support of the visual system conceptually specified in 3.2 of this specification.

3.7.16.1 Mathematical statement of the problem.- The requirement for controlling and operating the visual system shall be stated mathematically. The rationale and the analysis for any simplification of any of the equations derived to the form which is implemented in the digital computer system shall be present.

3.7.16.2 Error analysis.- An error analysis shall be made to determine if the equations derived will meet the performance and accuracy requirements of the visual system specified therein.

3.7.16.3 Definitions and symbols.- The mathematical symbols used shall be in accordance with MIL-STD-106 and David Taylor Model Basin Report 1319 where applicable.

3.8 Electromagnetic Interference (EMI) suppression.- The equipment shall be designed to meet the CE03, CS06, and RE02 requirements of MIL-STD-461. In addition, EMI design practices shall be utilized to ensure system self-compatibility and freedom from internally generated nuisance electrical problems.

3.8.1 Electrical bonding.- The electrical bonding procedures of MIL-STD-1310 shall be utilized as a design guide.

3.9 Dimensions.- The unassembled visual system shall be capable of passage through a 10 x 10 foot high doorway. Dimensions of all subsystems and items shall be such as not to interfere with the pilots field of view and such as not to mechanically interfere with any other subsystem or system.

3.10 Weight.- The weight for individual components, subsystems or systems shall be in accordance with MIL-T-23991 and MIL-STD-1472 such as not to constitute a hazard when removal is required for replacement or maintenance functions.

3.11 Color.- The selection of colors for the visual system and trainer additions shall be in accordance with MIL-T-23991 and shall match and blend with the colors of the existing equipment to which they will be added.

3.12 Finish.- Finish shall be in accordance with requirements of MIL-T-23991.

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3.13 Nameplates and product markings.- Markings shall be in accordance with MIL-T-23991. Conductors shall be coded in accordance with MIL-STD-681.

3.14 Government-furnished property.- The contractor shall have access to the trainer cockpit, motion platform and computer on a scheduled basis.

3.15 Workmanship.- Workmanship shall be in accordance with Requirement 9 of MIL-STD-454.

4. QUALITY ASSURANCE PROVISIONS

4.1 General.- The general quality assurance provisions of MIL-T-82335 shall apply.

4.2 Demonstrations.- The following demonstrations shall be provided:

4.2.1 Reliability demonstration.- A 1420 hour (two calendar months) reliability/availability demonstration consisting of 832 hours operational time with the balance being maintenance and power-off time shall be performed as specified in MIL-T-23991. Operations shall be representative of training missions performed during a scheduled training course.

4.2.2 Maintainability demonstration.- A maintainability demonstration shall be performed at the installation site of the visual system in accordance with the Maintainability Demonstration requirements of MIL-STD-471 and the Government-approved, contractor-prepared demonstration plan. The following additional criteria shall apply:

(a) Test Method 1, Plans A1 and B1 of MIL-STD-471 shall be utilized

(b) Indices to be demonstrated: M_{ct} and $M_{max_{ct}}$

(c) The demonstration shall be conducted by Government personnel who have successfully completed the on-site contractor-conducted training program, using only those tools, equipment, data, training personnel, and material resources which have been programed and provided as a result of the trainer contract. Conduct of the demonstration shall be predicated upon the normal operation of the trainer during training situations. However, if normal operation of the trainer does not result in a conclusive accept or reject decision, simulated failures may be used to supplement actual failures in order to arrive at a conclusion (subject to approval of the Procuring Contracting Officer)

(d) Contractor participation during conduct of the demonstration shall be limited to the following:

(1) Preparation of demonstration plan

(2) Training cognizant demonstration personnel in the objectives of the program and the techniques which will be used to gather required data

(3) Observation of demonstration tests, recording all data and preparation of the Maintainability Demonstration Report

(e) Government participation during conduct of demonstration will include the following:

(1) Conduct of maintainability demonstration

(2) Performance of maintenance services during the demonstration period

(f) If the visual system should fail to meet any of the quantitative maintainability requirements specified herein, it shall be the contractor's responsibility to correct all deficiencies (hardware and software) which are attributable to such failure(s). Corrective actions shall be promptly accomplished on a "not to interfere with scheduled training" basis

(g) Any necessary retest following corrective action(s) shall be as directed by the Procuring Contracting Officer.

4.3 Inspections.- Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements. Except as otherwise specified in the contract, the supplier may utilize his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specfication where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.3.1 In-process inspection.- The in-process inspection shall include the following items:

(a) Materials

(b) Parts

(c) Provisions

(d) Interchangeability

(e) Safety

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(f) Mechanical design

(g) Electrical and electronic design

(h) Reliability

(i) Transportability

(j) Maintainability

(k) Electromagnetic interference suppression

(l) Color

(m) Finish

(n) Nameplate and product markings

(o) Workmanship

(p) Wire marking

(q) Accessibility.

4.3.2 Quality conformance inspection.- Quality conformance inspection shall be in accordance with the approved Trainer Test Procedures and Results report of the contract and shall consist of the following examinations and results:

4.3.2.1 Examinations.- Examinations shall be in accordance with MIL-T-23991.

4.3.3 Tests.- A test plan shall be submitted for all system and subsystem tests specified herein. A test plan shall be included in the Preliminary Submission of the Trainer Test Procedures and Results Report. The following tests shall be performed:

(a) Functional

(b) Systems integration

(c) Electrical

(d) Grounding and grounding systems

(e) Electromagnetic interference suppression

(f) Structural

(g) Human factors.

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(For subsequent units of the same visual system only tests necessary to assure quality control should be specified.)

4.3.3.1 Functional tests.- Functional tests shall be prepared to demonstrate and substantiate the performance of each functional operation of the system. The system shall be capable of meeting functional tests without alinement or adjustment of controls, other than the accessible controls employed for normal system operation. No repairs or adjustments shall be permitted during the conduct of functional tests. If any repairs or adjustments are required, the test in question, as well as any other tests whose results may be affected thereby, shall be repeated after repairs or adjustments have been made.

4.3.3.2 Subsystem tests.- Tests shall be performed on the following subsystems:

(a) Television systems

(b) Background display system

(c) Display screen

(d) Optical systems

(e) Models

(f) Servo, gantry, and gimbal systems

(g) FLOLS system

(h) Computer and interface

(i) Controls.

4.3.3.2.1 Television systems tests.- The target and background television systems and components shall be subjected to the following tests:

(a) Horizontal and vertical resolution of pickup and display components

(b) Gray scale

(c) Video bandwidths

(d) Video signal levels

(e) Noise levels

(f) Aperture correction

(g) Gamma correction

(h) Linear phase characteristics

(i) Impedance matching

(j) Hum

(k) Target projector blanking.

4.3.3.2.2 Display screen tests.- The display screen tests shall be performed to verify compliance with 3.7.1 of this specification. The tests shall include the following:

(a) Screen radius

(b) Uniformity of curvature

(c) Seam visibility

(d) Screen gain.

4.3.3.2.3 Optical system tests.- The optical systems test plan shall use MIL-STD-150 as a guide. The following optical tests shall be performed:

(a) Focal length, back and front focal distances, as a function of the zoom position, where applicable

(b) Size and position of the entrance pupil for camera lenses and the exit pupil for projection lenses as a function of the zoom position, where applicable, or as a function of field angle for wide angle lenses

(c) Relative illumination as function of field angle

(d) Resolving power as a function of field angle and zoom position, where applicable, and a spectral distribution of illumination equal within 10 percent to that of the normal system operation

(e) Distortion

(f) Image size and actual field of view

(g) For the target camera lens, depth of field as a function of range and the corresponding zoom position.

4.3.3.2.4 Model tests.- The target and background models and the illumination of the models shall be tested to verify compliance with 3.6 and 3.7 of this specification.

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4.3.3.2.5 Servo, gantry, and gimbal system tests.- The servo, gantry and gimbal systems shall be tested for compliance with 3.2.4 of this specification. Constant error curves for 0.5 percent and 0.1 percent tracking errors shall be provided for each servo. Additional tests shall include but not be limited to the following:

(a) Motion excursion limits

(b) Velocity limits

(c) Acceleration limits

(d) Positional accuracy

(e) Threshold sensitivity

(f) Repeatability

(g) Smoothness of operation

(h) Jitter

(i) Vibration

(j) Frequency response

(k) Deceleration limits.

4.3.3.2.6 FLOLS system tests.- The FLOLS system shall be tested to verify compliance with 3.6 and 3.7 of this specification.

4.3.3.2.7 Computer and interface tests.- The computer and interface tests shall be performed to verify compliance with 3.7.15 of this specification.

4.3.3.2.8 Controls tests.- The controls shall be tested to verify compliance with 3.7.8 of this specification.

4.3.3.3 Systems tests.- The following tests shall be performed on the integrated background and target visual systems:

(a) Horizontal and vertical resolution as a function of field angle consistent with the combined requirements of image luminance, and shades of gray

(b) Target and background gray scale

(c) Separate target and background image luminance as a function of field angle

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(d) Separate target and background image highlight luminance

(e) Target and background image distortion

(f) Target image size as a function of range

(g) FLOLS image size and position relative to the target image as a function of range and viewing direction

(h) Target image and FLOLS image tracking accuracy

(i) Field of view

(j) Image jitter

(k) Target image insetting.

4.3.3.4 Systems integration tests.- Systems integration tests shall be performed by having at least three qualified Navy pilots perform five successive successful field and carrier landings. Further tests will be performed by the Government to verify mission capabilities.

4.3.3.5 Electrical tests.- Electrical tests shall be performed in accordance with MIL-T-23991.

4.3.3.6 Grounding and grounding systems tests.- Grounding and grounding systems tests shall be performed to verify 3.2.3.3. of this specification.

4.3.3.7 Electromagnetic interference suppression tests.- Electromagnetic interference suppression tests shall be performed to verify 3.8 of this specification.

4.3.3.8 Structural tests.- Structural tests shall be performed to verify 3.2.2. of this specification.

4.3.3.9 Human factors tests.- Human factors engineering compliance tests shall be performed in accordance with MIL-T-23991 including verification of accoustical noise requirements of this specification.

4.3.4 Test methods.- The following test methods shall be used:

4.3.4.1 Image size measurements.- Image size on the screen shall be measured in terms of viewing angle subtended from the nominal eye position in the cockpit. Measured angles shall be compared with the theoretically expected values.

4.3.4.2 Target image distortion.- Rectangular templates shall be prepared for use at the pickup and the display to measure total system distortion. The templates shall be centered in the field-of-view and shall be of a size to present rectangles at the final display whose sides are 80, 50, and 30 percent of the maximum instantaneous field-of-view dimensions.

4.3.4.3 Image quality.- Runway alinement determination shall be performed in the static mode (optical probe shall be manually drifted laterally across runway centerline extension at a range of four nautical miles) using five qualified Navy pilots. At least six runs shall be made for each pilot and a judgement shall be obtained on each run based on visual observation only, as to the lateral position of the aircraft when lined up with the runway.

4.3.4.4 Photometric measurements.- Background and target image luminance, and FLOLS light intensity shall be measured with a photometer at the nominal eye position in the cockpit. Luminance of the background and target images shall be measured independently. During luminance tests, all sources of light on the screen shall be extinguished except the projector under test.

4.3.4.5 Field-of-view measurements.- Projected field-of-view measurements shall be with respect to the nominal eye position in the cockpit.

4.3.4.6 Resolving power measurements.- Resolving power shall be measured with high and medium contrast USAF test charts at the focus setting of normal operation. Measurement of modulation transfer functions will be acceptable as a substitute for these resolving power measurements.

4.3.4.7 Servo system measurements.- The low speed tracking error of each servo system shall be determined by a linear ramp input. The rate of the linear ramp input shall be 1 percent of the maximum rate of the servo under test.

4.3.5 Test equipment and instrumentation.- All test equipment and instrumentation other than standard laboratory equipment such as oscilliscopes, photometers. etc., necessary to conduct tests of 4.3.3 shall be supplied by the contractor. The test equipment shall be checked and calibrated within one month prior to testing.

4.3.5.1 Photocells.- Photocells for photometric measurements shall be cosine corrected and shall not deviate by more than 10 percent from the standard eye.

4.3.6 Reliability testing.- Reliability testing will be to a test plan developed in accordance with test plan XXV of MIL-STD-781. The test plan shall define failures and relate to definitions in MIL-STD-781.

4.4 Facilities, equipment and personnel.- The contractor shall furnish all facilities, equipment and personnel that the Government requires to ensure that the trainer meets the requirements of this specification.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery requirements.- Since final acceptance will take place at the installation site, there is no specific preparation for delivery requirements. The system shall be packaged, packed and marked in a manner that will ensure acceptance by common carrier and safe delivery, off-loading and installation at destination.

6. NOTES

6.1 Intended use.- The visual system will be used for pilot proficiency training.

(Expand according to specific aircraft and training device mission.)

6.2 Definitions.- Definition shall be in accordance with MIL-T-23991. The nomenclature, glossary and sign convention of MIL-HDBK-141, MIL-STD-1241, and NAVSO P-3097 shall be used.

6.2.1 Terms used.- The following definition of terms shall be used in this specification.

6.2.1.1 Target.- Target shall mean the television imagery including the aircraft carrier, field landing strip, ground target, or another aircraft projected by the target projector.

6.2.1.2 Contrast.- Contrast is defined as $(L_{max} - L_{min}) / (L_{max} + L_{min})$ where L_{max} is maximum screen luminance and L_{min} is minimum screen luminance.

6.2.1.3 Optical distortion.- Optical distortion shall mean the correlation between the coordinates in primary object space and final image space with reference to the straight forward line of sight of the trainee. Optical distortion is defined herein as $(\emptyset - \emptyset')/(\emptyset \times 100)$ percent where $\emptyset$ is an angular coordinate in object space and $\emptyset'$ is the corresponding coordinate in final image space.

6.2.1.4 Bolter.- A bolter shall mean an unsuccessful hook capture during carrier landing.

6.2.1.5 General purpose digital computer.- A general purpose digital computer is a stored-program, automatic-sequence digital computer possessing a memory randomly accessible at the basic machine cycle time (for both instructions and data), with a general input/output capability, and with the ability to perform instructions in any arbitrary sequence which can be self-modified.

6.2.1.6 Computer word length.- Computer word length is the number of bits, establishing magnitude and sign in a single-precision data operand, operated upon for computational and logical purposes in an arithmetic unit of the computer and does not include parity, check, error correcting, or other noncomputing bits.

6.2.1.7 Interface equipment.- Interface equipment is the equipment that controls, transmits, encodes, decodes, converts, or buffers analog, digital, or discrete information passing between the computer, the trainer stations, and visual system; e.g., digital-to-analog, analog-to-digital, digital-to-discrete, and discrete-to-digital converters, digital-to-synchro converters and the like.

6.2.1.8 Operator.- Operator shall be synonymous with instructor.

6.2.1.9 Subject.- Subject shall be synonymous with pilot.

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